COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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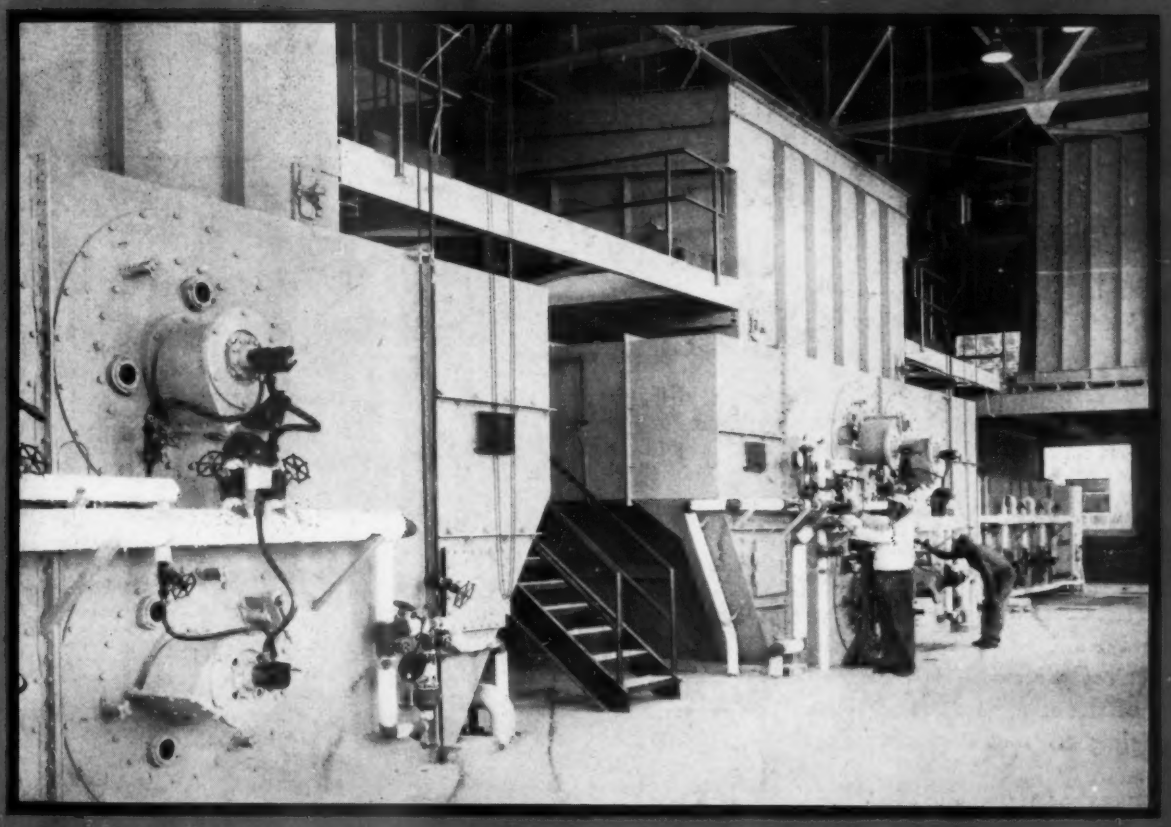


Foreground—two new 120,000-lb per hr oil-fired units in a Southern paper mill

More Power for Alkali Production ▶

Early Developments in Pulverized Coal—Part 2 ▶

The General Fuel Situation ▶

Recent C-E Steam Generating Units for Utilities

WHITE RIVER GENERATING STATION

INDIANAPOLIS POWER & LIGHT COMPANY

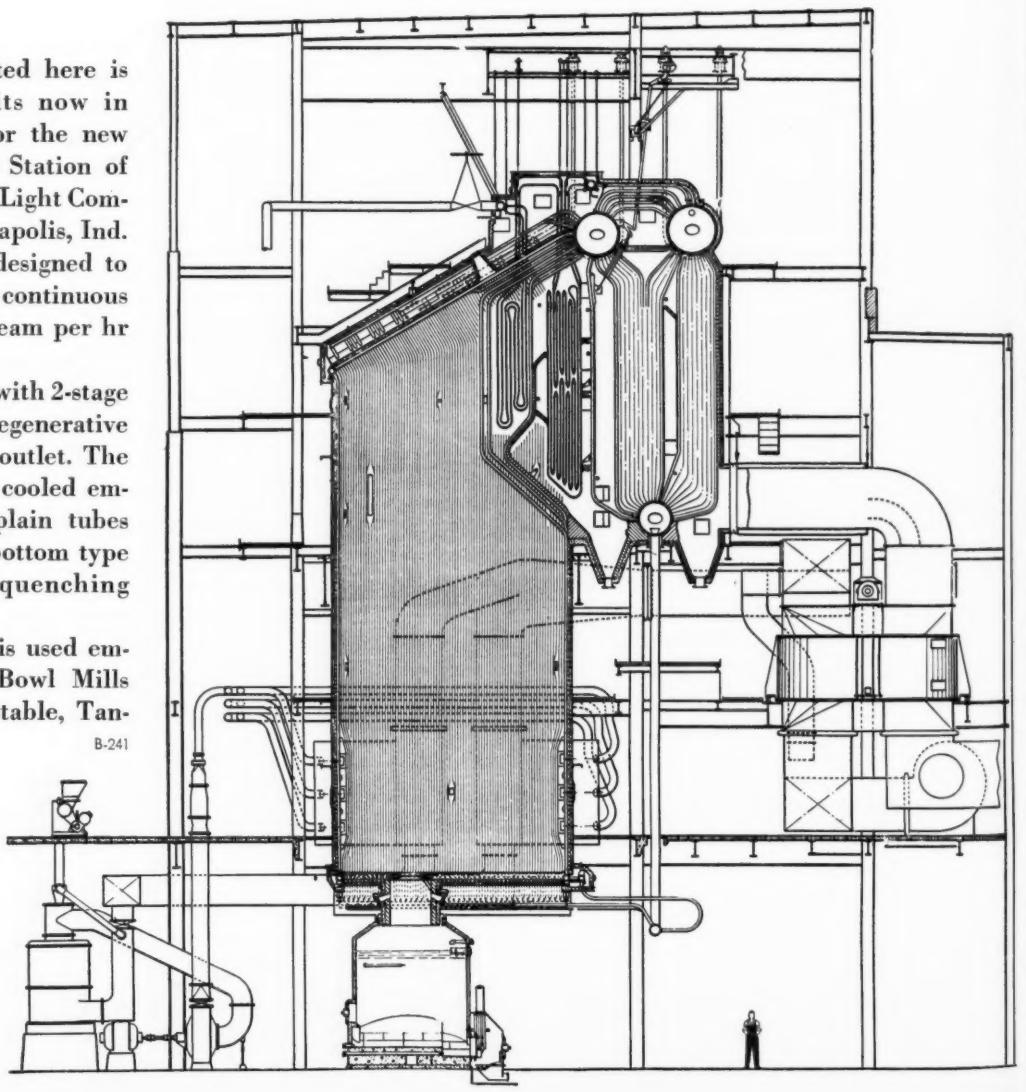
THE C-E Unit illustrated here is one of two such units now in process of fabrication for the new White River Generating Station of the Indianapolis Power & Light Company southwest of Indianapolis, Ind.

These units are each designed to produce, at maximum continuous capacity, 400,000 lb of steam per hr at 875 psi and 900 F.

They are 3-drum units with 2-stage superheaters and have regenerative air heaters at the boiler outlet. The furnaces are fully water cooled employing closely spaced plain tubes and are of the slagging bottom type discharging to water quenching hoppers.

Pulverized coal firing is used employing C-E Raymond Bowl Mills and C-E Vertically-adjustable, Tangential Burners.

B-241



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C-E PRODUCTS INCLUDE ALL TYPES OF BOILERS, FURNACES, PULVERIZED FUEL SYSTEMS AND STOKERS; ALSO SUPERHEATERS, ECONOMIZERS AND AIR HEATERS

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWENTY NUMBER FOUR

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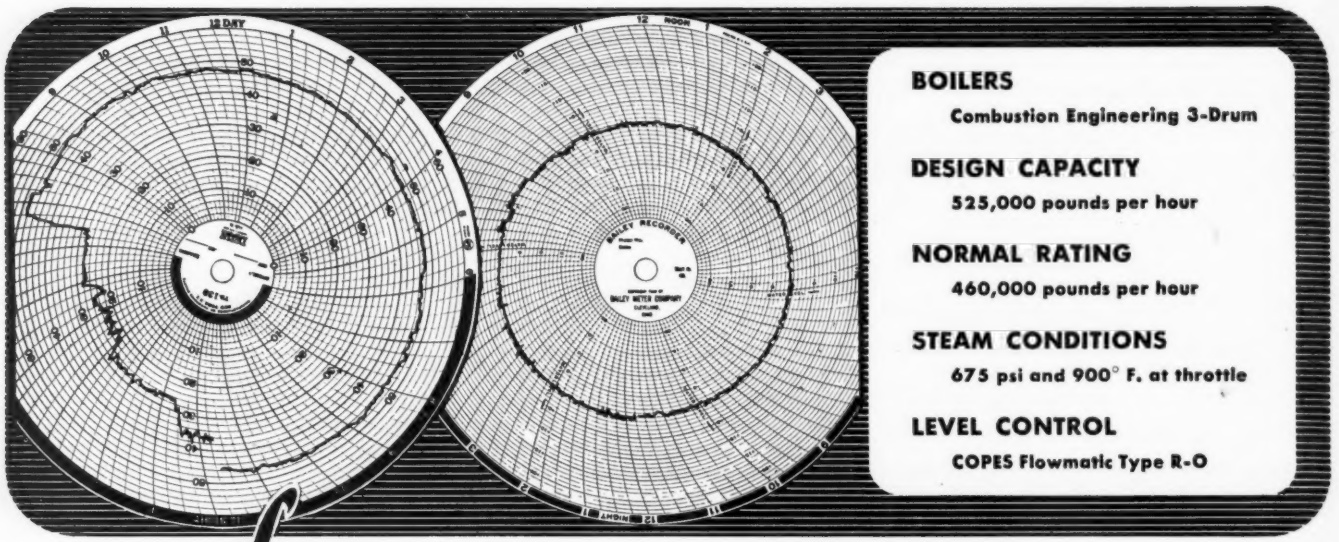

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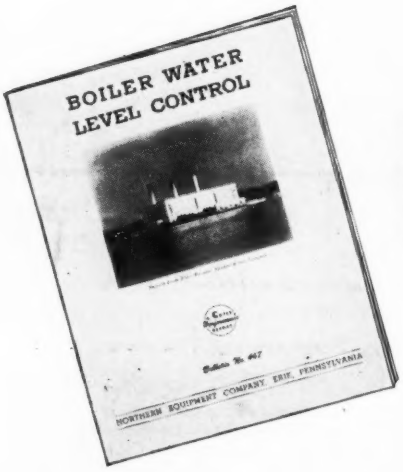

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EDITORIAL

Steam Quality

Changing practice has outmoded a number of terms once commonly employed in power engineering, such as "boiler horsepower," "factor of evaporation," "per cent rating," etc.; but there are a few others that persist despite excellent reasons for change. One of these is "steam quality" used to define the percentage by weight of dry saturated steam contained in a pound mixture of steam and entrained moisture. The term is still found in textbooks, in the Power Test Code on Boilers, and is employed in boiler tests. Not that what it designates has lost force, but modern conditions have rendered the term itself misleading.

The word "quality" as defined by the dictionary and by common usage is synonymous with character, nature, class, grade or excellence, and some of the larger dictionaries also include its accepted application to steam—a definition that was fixed many years ago before much, if any, attention was given to impurities in steam. Granted that in practice there are certain relations between wetness and entrained impurities, would it not be more logical to employ the term "dryness factor" when referring to this condition of steam and perhaps, in time, the term "quality" might be applied more properly to its purity.

Boiler Age

Our attention was recently called to the existence of two old Heine boilers in a midwestern manufacturing plant which are still in daily operation, at reduced pressure, after fifty-two years of service. Moreover, they have lately been provided with modern stokers to increase their steaming capacity. Other comparable cases can be recalled, all of which indicate that age alone is not the determining factor in boiler life.

Many will remember a paper which was presented at the 1947 A.S.M.E. Semi-Annual Meeting in Chicago, reporting metallurgical examination of sections cut from drums of old boilers removed from Waterside Station, New York, following more than forty years' service. The metal in this instance gave no evidence of any deterioration.

Physically, it is the operating conditions leading to such things as corrosion, caustic embrittlement and strain-aging that must be guarded against by careful inspection and proper maintenance, lest normal boiler life be jeopardized. But even in the absence of such physical deterioration it is obsolescence, measured by advancing practice, inadequacy to meet growing demands of output and economy, and reduced allowable pressure that usually prove the governing factors in boiler replacement.

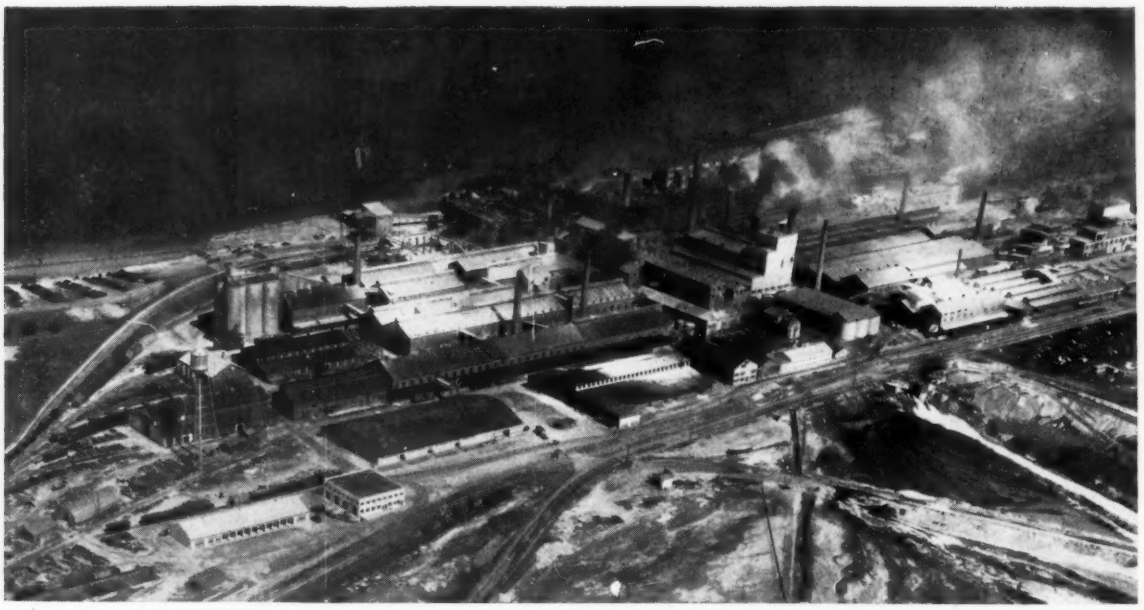
Obviously, the numerous instances of long boiler life that have thus far come to light concern units operating at relatively low pressures and temperatures and moderate steaming rates. It is for the future to reveal the life of modern high-pressure, high-temperature steam generating units which are subjected to much more exacting operating conditions. However, they are, in general, being given closer and more expert supervision than were their predecessors and this should tend to promote long life.

Within the Stacks

The old adage that "appearances are deceiving" is particularly applicable in the case of funnels of modern liners. In the old days the function of the conventional "smoke stack" was solely to carry away the products of combustion from the boiler uptakes and assist in providing the necessary draft. Then as marine boilers became larger and their number per ship decreased, either the number of funnels was decreased or the excess was used to house tanks and ducts. With streamlining applied to modern passenger vessels the employment of one or two large diameter funnels has afforded extra space to house additional appurtenances. This practice has been carried to a high degree in the case of the new British liner "Caronia," now building, and described in a recent issue of the *Shipbuilding and Shipping Record*. Here the single funnel will serve a number of purposes including a group of six smaller stacks from six boilers, the induced-draft fans serving each, several dust collectors and washers, and numerous ventilating ducts.

Another publication recently described a new motorship in which the captain's quarters, along with certain equipment, were housed in the single large stack.

One might infer from this that designers of stationary power plants, with their single-purpose stacks, have overlooked possibilities; but who can forecast what streamlining may yet do to the power plant of the future? Just at present, however, economics and utility have precedence over aesthetic considerations in power plant design.



Painesville plant of Diamond Alkali Company; power plant right of center

More Power for Greater Alkali Production

A description of the new extension to Diamond Alkali Company's power plant at Painesville, Ohio, which is equipped with a 300,000-lb per hr 1500-psi boiler complete with auxiliaries and a 15,000-kw turbine-generator. This installation was specifically designed for operation with 100 per cent makeup.

By NEIL J. BRASKI

Design Engineer, Central Engrg. Dept., Diamond Alkali Company

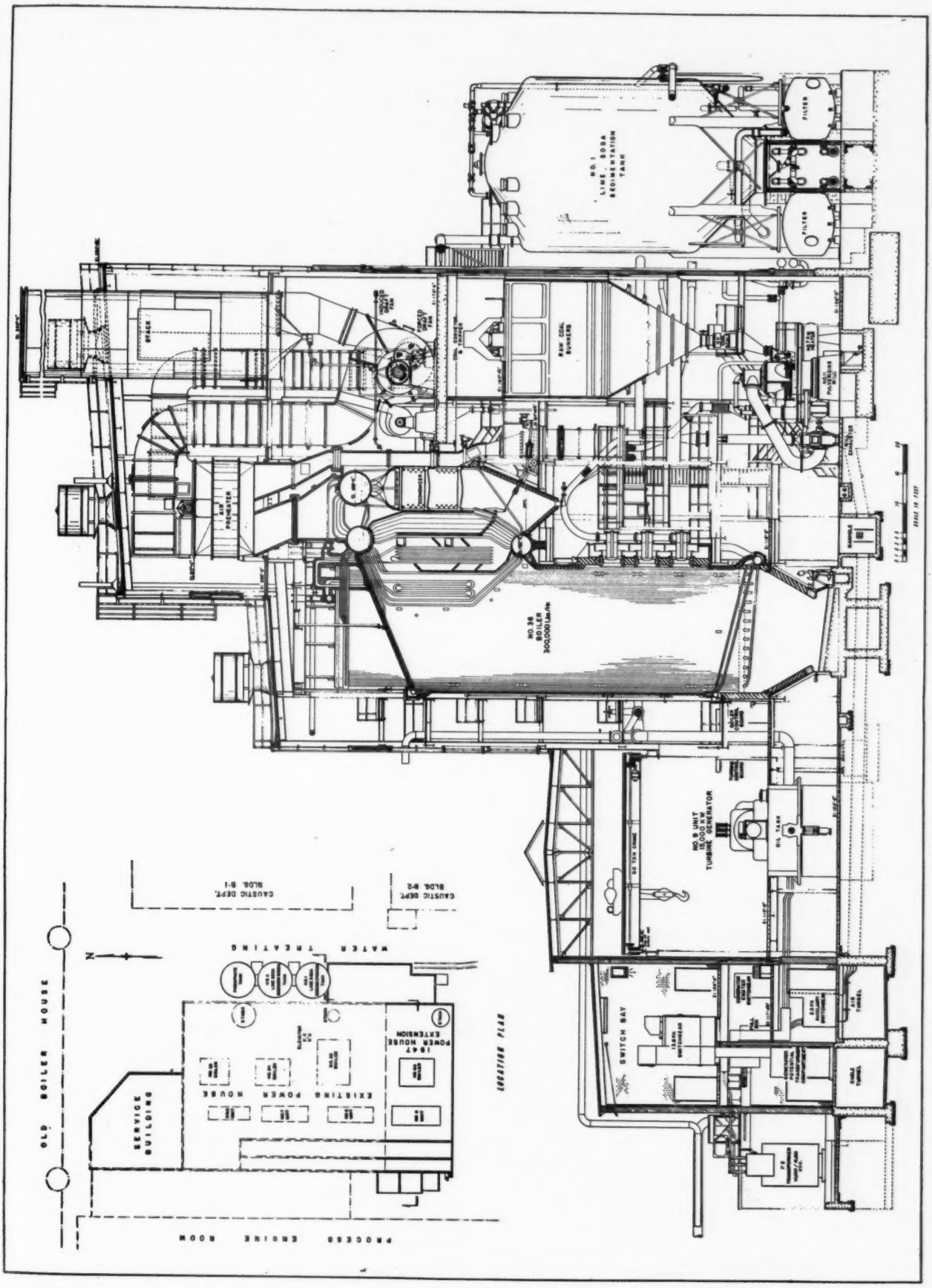
REFLECTING the "latest word" in equipment developments and operational improvements, a new steam and electric generating facility will soon be put into operation by Diamond Alkali Company at its Painesville, Ohio, chemical manufacturing plant, one of the world's largest for tonnage production of soda ash, caustic soda, bicarbonate of soda, and their specialized derivatives or related products.

The new extension, involving a capital expenditure totaling approximately $3,100,000, will give Diamond an overall rated generating capacity exceeding 1,000,000 lb per hr of steam and over 50,000 kw of electric power for the chemical processing operations at Painesville. These figures represent an approximate increase of between 25 and 30 per cent in steam and electric power-producing capacity.

This extension, the third made to the original building erected in 1929, is 140 ft long, 58 ft wide, and 128 ft high. Similar in design to the existing structure, it features permanent walls of steel frame, brick and stone construction, with the upper portion and temporary south wall combining steel frame and transite.

Principal units comprise a new high-pressure boiler of 300,000 lb per hr capacity complete with auxiliaries, a new 15,000-kw turbine-generator, a 180,000-gph water-treating plant, and a combination maintenance shop and employee service building. From the viewpoint of equipment and its operation, the installation is unique in that it has been specifically designed to handle 100 per cent feedwater makeup, and to provide unusual flexibility for maintenance of the plant steam balance.

Plans for expanding its power plant were initially launched by Diamond in 1945. At the Painesville chemical plant, as was the case with numerous other industrial plants throughout the nation, wartime demands for peak production of military supplies severely taxed steam and electric generating facilities then in use 'round-the-clock. The necessity of meeting and maintaining maximum load conditions on a full-time basis, coupled with the resultant wear-and-tear imposed on certain units of equipment, soon led the company's engineers to formulate plans for a new addition to the power plant. The final result is the $3,100,000 extension which is expected to be put into service late this year. Consulting engineers for the project were Gilbert Associates, Inc.,



Sectional elevation of new extension to power plant of Diamond Alkali Company at Painesville, O.

of Reading, Pa., who collaborated with Diamond engineers in designing and engineering this new addition.

Several interesting engineering considerations guided the selection of the boiler and its auxiliaries, the turbine-generator, and other equipment purchased. These factors figured, one way or another, in "custom-tailoring" this installation from the design viewpoint to meet the special operating requirements imposed by type of water supply available, usage of power output, etc.

Coal-Handling System

Dumped directly from cars on a rail trestle into a Stedman crusher and thence distributed by a Link Belt tripper to the various boiler bunkers, coal will be carried to the steam generator by a 58-ft extension of the conveyor system which now comprises two 170-ft rubberized canvas belts.

Newly installed raw-coal bunkers are of the conventional sectionalized type, with three sections of sufficient capacity to provide a fuel supply for 30 hr continuous operation. Each section has a 70-deg hopper and all interior surfaces are coated with a 2-in. layer of Gunite to protect them against erosion and corrosion. To facilitate movement of wet coal into weighing scales, eight air jets have been installed near the outlet of each spout and are arranged to blow tangentially.

From each bunker spout coal flows through a special gate directly into a Richardson scale. Thus, in contrast to many current coal-handling installations, there is no chute between the scales and the bunkers. This arrangement will avoid the troubles normally involved with sticking of wet coal in the chute.

Of totally enclosed and dust-proof construction, these all-electric, automatically operated hopper scales have a unit capacity of 200 lb and an hourly capacity of 15 tons each. Also, they are equipped with a "no-flow" indication signal that provides a visual warning at the control board when coal sinks below a predetermined level due to interruption of flow.

Coal (West Virginia bituminous) is pulverized by a trio of Raymond No. 353 bowl mills, each handling 20,300 lb per hr. These capacities are based upon use of coal possessing 12 per cent maximum moisture. It is planned to use two mills for regular plant operation, with the third allocated to standby service.

Pulverizing mills and integral exhausters are powered by Elliott 200-hp, 2300- v,a-c squirrel-cage induction motors. These mills take advantage of a recent innovation in pulverizer design, namely, introduction of hot air to the pulverizing zone by means of an 8-in. pipe installed through the top of the unit. This feature is expected to prove especially advantageous by speeding-up drying of unusually wet coal, thereby making it possible to maintain pulverizer operations close to maximum capacity at all times.

Coal feeders, of the standard conventional type, are located on the side of each mill. They are driven by Standard Sterling Speedtrol (variable-speed) units, which incorporate mechanical level control.

Steam Generation

The new boiler is the fourth high-pressure unit to be installed in Diamond's Painesville plant. The first, of 700 psi, went into service in 1929; the second, an 800-psi unit, in 1935; and the third, a 2200-psi installation, in 1939. This third steam generator was one of two highest pressure units in the U. S. at that time, and the greater part of its design and development, and its auxiliaries was pioneered by Diamond engineers.

Each boiler is connected to its own turbine-generator. With the exception of a single line between the 700-lb and the 800-lb units, the boilers are not interconnected. Because the entire output of these units is used for process work at 150 psi, the high-pressure turbines, including the new one, are of the straight back-pressure type. Two smaller General Electric turbine-generators, of 2000 kw and 5000 kw capacity, respectively, with each unit operating on the 150-psi condensing cycle, serve to balance steam and electric loads.

Due to the knowledge and experience gained with high steam pressure, Diamond engineers naturally thought in terms of duplicating the last unit when power expansion discussions first got under way. Installation of another 2200-psi boiler, therefore, received serious consideration initially. However, planning veered toward a lower pressure unit after a thorough investigation of both existing and probable process steam versus electrical demands clearly indicated that more than enough power would be secured economically from needed steam output at 1500 psi to meet all plant requirements. Consequently, with demand for utilizing the extra power available from 2200 psi steam lacking, there was no economic justification for exceeding the 1500-psi level, especially in view of the fact that the higher pressure unit would have entailed substantially increased cost.

Furthermore, due to the trend of standardization in steam pressures and temperatures, boiler and turbine manufacturers were reluctant to quote on higher pressure "tailor-made" equipment because of the extra engineering involved. When orders were placed for this equipment in 1945, engineering was one of the bottlenecks in delivery and it was felt that earlier delivery of the 1500-lb equipment was more important economically than the greater operating economy of a higher pressure unit, especially since the advantages of this greater economy could be realized only through unforeseen changes in plant heat balance.

Another important consideration in favor of the lower pressure unit was the fact that the 1500-psi turbine required almost twice as great nozzle and blade areas as the 2200-psi units. This is an important factor in reducing loss of capacity due to blade deposits which had been the only serious problem in the operation of the 2200-psi turbine-generator.

Although the capacity of the new turbine was based on an initial steam temperature of 900 F in order to maintain an exhaust temperature under 500 F, the unit, nevertheless, is designed to withstand 950 F total temperature for additional safety and operating margin.

The steam generator selected is a Combustion Engineering Type VE three-drum unit designed to provide 300,000 lb per hr at 1500 psi operating pressure and a temperature of 900 F at the superheater outlet. Guaranteed overall efficiency at maximum continuous load is 85.6 and somewhat higher at lower loads.

To cope with constantly changing conditions in the chemical industry it was essential that the heat balance of the new boiler unit and feedwater heating system be made as flexible as possible. Therefore, the boiler is de-

signed for operation with a feedwater temperature at the economizer inlet of anywhere between 220 F and 350 F. Since the present heat balance dictates a steam-power ratio of 19.3 lb of steam per kilowatthour, the initial operation will be at 220 F. If power requirements increase faster than steam requirements, the feedwater temperature can be increased, thus utilizing 150 lb exhaust steam from the new turbine for feedwater heating. At 350 F the steam-power ratio of the installation becomes 16.1 lb of steam per kilowatthour and the boiler capacity is increased to 330,000 lb of steam per hour.

Since use of 100 per cent makeup is mandatory (steam generated being used exclusively for process and is nonrecoverable), the boiler is designed for a conservative furnace heat release of 17,400 Btu per cu ft per hr. The unit is suited to burning fuel oil up to one-half load although the main fuel will be pulverized West Virginia bituminous coal having a heat value of 13,000 Btu per lb, 12 per cent ash and 60 Hardgrove grindability.

The coal burners are of the "RO" horizontal turbulent type and comprise six units arranged vertically in pairs. Whereas general practice provides for horizontal arrangement of two rows of three burners each, the Diamond set-up has been devised to help minimize flame impingement on the side water wall and reduce slag formation troubles.

Provision is made for installation of a Todd mechanically atomized combination light-oil torch and Bunker C oil burner, the oil torch serving to ignite pulverized coal and the heavy oil burner being intended for use as a load burner under emergency conditions or for starting up. This latter application is noteworthy since it will eliminate the need of intermittent pulverizer operation ordinarily required when starting up a pulverized-coal-fired boiler.

Whether used as a pilot light or a load burner, the oil burner is ignited by two C-E pneumatically retractable oil torches centrally located in relation to the six coal burners. Both torches are equipped for continuous electric ignition. One is equidistant from the upper four burners, the other being similarly located with respect to the lower four burners. Affording a convenient means for the igniting oil burners inserted in the lighting tubes of the coal burners, each torch is supplied with 40 to 50 gph of light oil and air at 65 psig for atomization and for propelling the spark into the oil spray.

Light oil for ignition, obtained from a 2000-gal storage tank adjacent to the new building, is pumped to the boiler by two Gerotor rotary pumps of 10 gpm each. Bunker C fuel oil, drawn from the regular plant supply, is handled by a Todd system incorporating a DeLaval IMO pump (21 gpm) and a Davis heat-exchanger.

The furnace is 24 ft wide by 21 ft deep and provides gross volume of 26,000 cu ft from 8310 sq ft of heating surface. It is completely water cooled with plain tubes on front, rear and sides, spaced $^1/_8$ in. apart, and fin tubes on the roof. Two rows of screen tubes are provided at the furnace bottom. The boiler section provides additional heating surface totaling 7090 sq ft.

For primary separation of water, a 48-in. separating drum is used. The offtake drum, of 60 in. diameter, incorporates a bubble-type washer and screen-drier. The unit has a plastic casing made up of a double coating of Gunite refractory, a single course of magnesia block and two layers of plastic insulation. That part of the setting below the lower water-wall headers and furnace hopper is made up of a single row of insulating brick and a double row of firebrick.

Boiler Auxiliaries

So much for the boiler proper. The auxiliaries and other equipment of the unit include an Elesco superheater, an Elesco economizer, a Ljungstrom regenerative air preheater, Sturtevant induced-draft and forced-draft fans (one each), Allen-Sherman-Hoff ash-handling system, Cochrane deaerator, two Byron Jackson boiler feed pumps equipped with Worthington turbine drives and a Lummus feedwater heater.

Consisting of 68 two-loop elements in the primary stage and 69 six-loop elements in the secondary section, the two-stage interbank superheater is designed to raise steam temperature to 900 F when operating at an hourly rate of 300,000 lb at 1475 psi gage. Control of superheat will be achieved by means of a bypass damper located between the superheater and the economizer. This unit is designed to maintain a total temperature essentially constant at 900 F for boiler capacities ranging from 185,000 lb per hr up to 300,000 lb per hr with 220-F feedwater.

The economizer, an Elesco type, has horizontal fin tubes arranged to provide parallel flow and consists of 468 two-inch tubes arranged in two banks with a total heating surface of 12,460 sq ft.

The Ljungstrom regenerative air preheater of the vertical type is designed for counterflow of air and flue gases. It has an overall heating surface of 48,900 sq ft and is driven by a Westinghouse 5-hp motor and a Jones all-herringbone gear speed reducer. As a safety feature to prevent the air heater elements from burning out in case of power failure or motor outage, an air motor has been installed to permit continuing equipment operation. The preheater also has mechanically operated dual-nozzle soot blowers to simplify periodic plate cleaning and maintenance.

A Vulcan soot blower system serves the boiler. In addition to the usual number of stationary blowers, there are four retractable units. These are driven by electric motors in place of the conventional air-type units. The economizer is equipped with ten blowers, arranged in two sets of five units each, which have been installed through the forced air duct. All the soot blowers utilize 150 lb steam.

The boiler is served by one induced-draft fan and one forced-draft fan, both of which are located in front of the unit at the economizer level. This location was selected so as to place the fans on the same floor as those serving the other three boilers.

The induced-draft fan—a Sturtevant type driven by an Elliott 900-hp, 2300-v, 900-rpm induction motor—has a capacity of 206,000 cfm at 13.2 in. suction pressure. It has a double inlet with vane control and water-cooled bearings. Connected to the scroll of each inlet is an auxiliary fan for removing 66 per cent of the fly ash from the flue gas and depositing it in a hopper ahead of the fan. These two fans discharge into the suction of the main fan. Selection of the ash-removing type of induced-draft fan was dictated primarily by the desire to minimize maintenance.

Continuous disposal of fly ash from the auxiliary fan hopper will be accomplished by an Allen-Sherman-Hoff

Hydromix valve, which utilizes bearing drain water from the fans and the air preheater. The ash-laden water flows by gravity directly to a waste lake 500 ft from the power plant.

The forced-draft fan (also a Sturtevant unit) is the standard water-cooled bearing type with inlet vane control. Having a capacity of 116,000 cfm at 13.1 in. section pressure when handling 115 F air, it is driven by an Elliott 350-hp, 2300-v, 1200-rpm induction motor.

Flue gas from the induced-draft fan is discharged to a steel stack extending 45 ft above the power house roof. This stack, 15 ft in diameter, is coated inside with a Gunite lining 2 in. thick as a protective measure against corrosion.

Ash Handling System

The furnace, which is the dry bottom type, is equipped with an Allen-Sherman-Hoff ash-handling system. The ash hopper has two refractory-lined sloping trenches, each with an oscillating sluice nozzle at the lower end. Sluiced into a transfer sump, ashes are conveyed with transport nozzles to the main sump and are thence removed by an "ASH" Hydroseal materials pump to the waste lake about 500 ft away. A second pump serves as a spare. These pumps are rated at 1000 gpm and V-belt-driven by 60-hp, 1200-rpm, 2300-v motors.

An ASH Hydrovac system will cary fly ash from the economizer hoppers and stack hoppers to the main sump. It also will be used to handle pulverizer rejects. Due to the large capacity of these hoppers, the system need be operated only once a day.

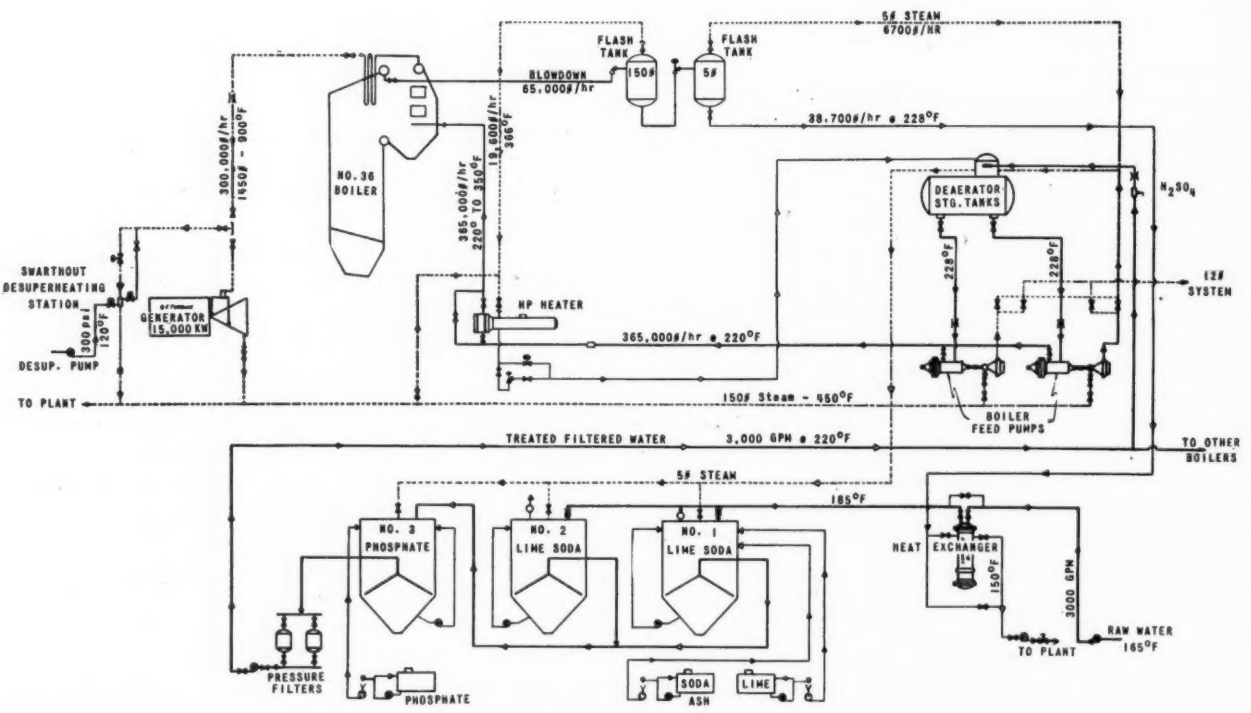
Feedwater Handling

Incoming feedwater is dearated in a Cochrane direct-contact type, horizontal deaerator and storage tank operating at 5 psi steam pressure. Designed to reduce the oxygen content of 375,000 lb of water per hour to 0.003 cc per liter or less, this unit incorporates an 8-ft diameter heater containing two sets of stainless steel trays. No vent condenser is required because non-condensable gases are exhausted with the outgoing steam to the lime-soda softeners at the water-treating plant, where the gases are vented to atmosphere.

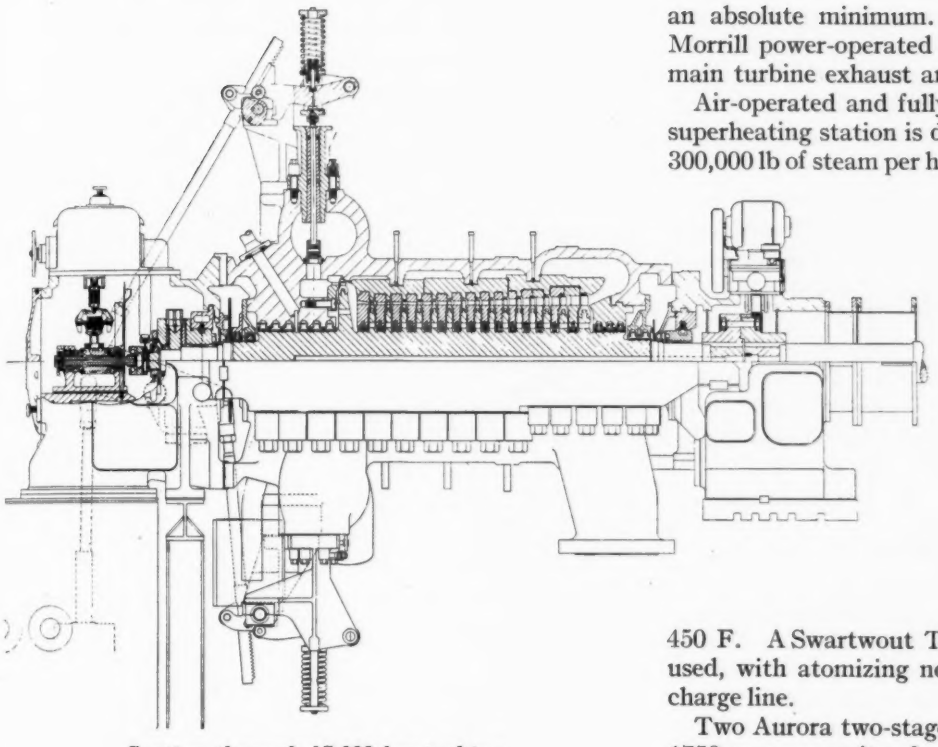
Installed on the ground floor of the plant directly below the deaerator are the two high-pressure boiler feed pumps of the Byron Jackson integral barrel, 8-stage type. Their capacity is 375,000 lb per hr each at 1700 psi discharge pressure while operating at 4000 rpm. The outer pump casing is of forged steel, with other pump parts (inner casing included) which come in contact with boiler feedwater constructed of 11.5–13 per cent chrome steel for maximum corrosion and erosion resistance.

Both feed pumps are turbine-driven by Worthington 1200-hp, 4060-rpm multi-stage non-condensing turbines, operating at 150 psi at the inlet and with 5 to 12 psi exhaust steam pressure. These units have oil-speed governors actuated by a spring-resisted bellows. Loading air pressure, which is determined by drum water level, steam flow and water flow, acts on the bellows to set the speed of the turbines, and water level regulation is thus accomplished by varying the feed pump speed.

A horizontal high-pressure feedwater heater of Lummus type has been installed to permit heating 350,000 lb of boiler feed per hour to any temperature up to 350 F. It features Multilok type head construction with 70–50 cupro-nickel U-tubes. The heating medium is 150-lb steam, supplied largely by the boiler blowdown flash system. When this is inadequate, supply can be supplemented with 150-lb steam from the regular plant system. As shown on the accompanying heat balance diagram, the heater is on the discharge side of the pump. Three motor-operated gate valves are incorporated in the feed line to the heaters so that bypassing the heaters can be accomplished quickly in case of tube failure.



Flow diagram of new unit



Section through 15,000-kw turbine

With boiler feedwater solids of 270 ppm, considerable blowing down will be required to maintain a boiler water concentration of 1000 ppm. Therefore, a continuous blowdown system has been installed. This installation consists of a Republic blowdown valve and two Cochrane flash tanks equipped with Swartwout water-level controllers and regulating valves. These tanks are connected in series.

The primary unit flashes steam at 150 psi and the secondary tank at 5 psi, the 150-psi flash steam going directly into the feedwater heater, while the 5-psi flash steam is piped to the deaerator. Additional heat recovery from blowdown water leaving the second flash tank can be secured by passing the water through a Lummus blowdown heat-exchanger used for heating raw water.

Piping and Valves

All high-pressure boiler feed and main steam valves (Crane and Walworth) used in this extension are of the newly developed 1500 lb pressure sealed-bonnet type with butt-weld ends. All shut-off valves are the gate type except the boiler non-return valve. The main steam valves are 1 per cent cast chrome molybdenum whereas the boiler-feed valves are of cast carbon molybdenum.

The main steam line to the turbine-generator is 10 in. Schedule 160, $^1/_2$ per cent chrome and $^1/_2$ per cent molybdenum alloy pipe (A280–46T), and is all-welded except for the single inlet flange on the top turbine casing. Boiler feed discharge piping is 6 in. Schedule 160 Grade "B" carbon steel (A-106). With the exception of flanges at the boiler feed pump outlets and feedwater heater inlet and outlet, this piping is also completely welded.

Crane prefabricated piping is used for all lines 6 in. and over, including the 150-lb, 12-lb, and 5-lb exhaust lines. Shop welding of main steam and boiler feed valves in the piping assemblies reduced necessary field welds to an absolute minimum. Two 12 × 14-in. Atwood & Morrill power-operated relief valves are installed in the main turbine exhaust and the desuperheating system.

Air-operated and fully automatic, the Swartwout desuperheating station is designed to reduce a maximum of 300,000 lb of steam per hour from 1450 psi 900 F to 150 psi 450 F. A Swartwout Type V2 pressure-reducing valve is used, with atomizing nozzles installed in the 16-in. discharge line.

Two Aurora two-stage turbine-type pumps of 50-gpm, 1750-rpm capacity furnish water for desuperheating steam at 300 psi. Driving these units are Elliott 30-hp back-pressure turbines. Flow, pressure and temperature of desuperheated steam are recorded by a Bailey recorder installed on the main turbine control board.

Electric Generating System

The main turbine is a General Electric 16-stage, 3600-rpm unit designed for 1450-psig throttle pressure, 950-F total temperature and 150-psig back pressure. It is similar in design and operating principles to the 2000-lb, 15,000-kw turbine installed in 1939, the principal difference being the valve arrangement. Whereas the old unit has a single steam chest on the top casing, the new one provides a steam inlet and a valve chest with three valves on both top and bottom casing. The object of this arrangement is to heat both of the casings equally, thereby avoiding temperature strains and consequent casing joint leakage.

The generator of the unit is a GE 15,000/22,500-kw, 3-phase, 60-cycle, 13,800-v hydrogen-cooled machine (15,000-kw at $^1/_2$ lb hydrogen and 22,500 kw at 15 lb hydrogen pressure). It has four vertical coolers in the stator. Current for the main exciter fields is supplied by storage battery in place of the conventional pilot exciter. For grounding the neutral of the generator winding, the impedance method is used with the primary of a 100-kva distribution transformer connected between the generator neutral and ground. The secondary of the transformer is short-circuited through a loading resistor. Power directional relays in the residual circuit of the feeder current transformers indicate ground location.

Power for boiler auxiliaries is normally supplied from the 13,800-v switch structure through an Allis-Chalmers 2500-kva, 13,800/2300-v transformer. An emergency connection between the auxiliary bus and one of the other boiler auxiliary buses has been provided to compensate for power failure to the auxiliary bus. This connection is so arranged that it closes automatically and restores power almost instantly so long as the failure is not caused

by trouble on the auxiliary bus. In this case, the closing relay energizing the breaker which completes this connection is locked out automatically.

The 13,800-v GE switchgear is of the modern metal-enclosed phase-isolated type with the bus sectionalized into two sections. The generator is connected to each bus section through a separate oil circuit-breaker, and one of the 10,000/13,333-kva transformers is connected to each section. During normal operation, both generator breakers will be closed, thereby energizing both sections of the bus. Also, both Allis-Chalmers 10,000/-13,333-kva transformers will be connected between their respective bus sections and the synchronizing bus, the transformers operating in parallel. This arrangement makes it possible to de-energize either section without power curtailment.

Controls and Instruments

Both boiler and turbine controls are centralized in a cubicle, with the boiler control board and the turbine instrument panel placed back to back. The enclosure is pressurized to keep out dust.

The Bailey combustion control system, completely automatic and air-operated, is designed for maintaining constant boiler pressure regardless of steam output by regulating fuel feed, coal-air ratio and forced and induced draft. A master pressure recording controller, which records the boiler drum pressure, provides the impulse to which all other controls of the set-up respond.

Boiler steam flow is recorded and integrated with a standard Bailey boiler meter, which also records air flow through the boiler. Feedwater to the boiler is metered at the suction of each feed pump. Telemeter transmitters at the pumps operate a single two-pen integrating recorder at the control board. Water level control is of the Bailey three-element type, this regulation being achieved through variation of feed pump turbine speed by a controller activated by an average impulse from steam flow, water flow and water level loading pressures. Drum water level is also recorded. Furnace drafts, secondary air and pulverizer air pressures are indicated on two six-point Bailey draft gages.

Superheat control, also fully atomatic, utilizes a Leeds & Northrup Micromax recording controller. This instrument operates a motor-drive unit that positions, in the last pass of the boiler, a bypass damper, which, by regulating gas flow through the secondary superheater, controls superheat temperature.

Temperature of air to pulverizers and the coal-air mixture leaving these units is recorded with a six-point Micromax temperature recorder having a three-section chart. Air-tempering dampers to the mills are regulated by L & N motive units providing manually operated pushbutton control from the boiler board. Air and gas temperatures and feedwater temperature to and from the economizer are recorded by an eight-point Micromax temperature recorder. As a continuous check on combustion efficiency, an indicating CO_2 meter is used.

The panel for the turbine-generator combination is arranged with turbine instruments on one side and generator instruments on the other, the two groups being separated by the hydrogen panel. Turbine instruments include Ashcroft stage-pressure gages, a Bailey desuperheated steam flowmeter and an L & N conductivity recorder, which is connected to sampling points ahead and following the superheater.

Among those instruments for the generator are a GE synchroscope, GE indicating wattmeter, L & N field temperature recorder and an L & N stator temperature recorder. The GE hydrogen panel is made up of purity-and-flow-indicating instruments which incorporate both audible and visual alarms to signal conditions requiring attention.

Boiler control and turbine instrument boards are similarly equipped. Alarm signals direct the operator's attention to service interruptions covering a wide range, chiefly motor failure, low water levels, high- and low-pressure conditions, fuel stoppage, flame failure and excessive temperatures. Also a system of interlocks is so arranged that a failure of the induced-draft fan will shut down the forced-draft fan and the pulverizers. A failure of the forced-draft fan will shut down the pulverizers only and failure of the pulverizers affect only the pulverizers and exhausters, the fans remaining in operation.

The water-treatment plant serving this extension is the outgrowth of a two-year boiler feedwater study conducted by Company engineers in collaboration with four consultants. As a result, this 180,000 gph plant has been specifically designed, engineered and equipped to meet certain operating conditions built around the use of 100 per cent lake water for boiler makeup. The system determined as best suited for handling the particular requirements involved is a lime-soda method of treatment with phosphate aftertreatment. It provides several noteworthy features as follows:

Lake water at 165 F, coming from process condensing and cooling equipment, is first fed into two large softening tanks for primary treatment with lime and soda ash. These units, affording an extra long retention period due to their large capacity, are equipped with spray heaters to bring the water up to 228 F. Sludge recirculation and automatic sludge blowoff are also employed.

Chemicals are handled both dry and in solution. There are five mixing tanks with recirculating and chemical feed pumps. Quantitative addition of lime, soda ash and phosphate is made with a Cochrane proportioner, which functions on a time cycle determined by water flow.

Following secondary treatment with phosphate similarly applied, the effluent is filtered in twelve Cochrane vertical pressure filters using "anthrafilt" as the filtering media. Then pH is corrected by the addition of sulphuric acid. For this operation, a Leeds & Northrup pH recording controller is used in conjunction with a Cochrane flowmeter. Together they regulate the amount of acid addition required. Of further interest in this connection is the fact that feedwater for each boiler is individually corrected as determined by the particular requirements of each unit.

Two separate power sources facilitate uninterrupted plant operation. In addition, all essential lines are double-piped and complete spare pumps installed to maintain continuous service.

Last but by no means least, this installation not only is expected to produce higher quality boiler water than previously obtainable at the plant, but more importantly, it will also provide far more accurate and positive control of water treatment in all its phases.

Additions to Utility Capacity

Scheduled additions to the installed generating capacity of Class I electric utility systems in the United States from July 1948 through 1951 will amount to over $15^1/_2$ million kilowatts. Of this, 3,043,835 kw applies to the second half of the current year; 5,158,450 kw will go into service next year; 4,473,981 kw during 1950; and 2,868,750 kw in 1951. These figures, contained in a Federal Power Commission report dated September 7, 1948, represent a $3^1/_2$-yr expansion of approximately 30 per cent, and will bring the total installed capacity at the end of 1951 up to nearly $66^1/_2$ million kilowatts. More than $1^1/_2$ million kilowatts was added during the first half of 1948. Of the existing installed capacity, approximately 69 per cent is steam, $28^1/_2$ per cent hydro, and $2^1/_2$ per cent internal combustion engines.

With some 50,933,000 kw installed as of June 30, 1948, the dependable capacity, including net firm power purchases, was around 49,870,000 kw; and, after deducting required reserves, the net *assured* capacity became 45,827,000 kw.

TABLE 1—PRESENT CAPACITY AND SCHEDULED ADDITIONS

Region	Installed Capacity as of June 30, 1948	Scheduled Additions, July 1948 through 1951
I	14,188,689	3,578,030
II	9,568,294	3,214,660
III	7,228,402	1,989,900
IV	6,662,571	1,980,575
V	2,974,617	1,399,380
VI	1,747,253	595,350
VII	3,663,698	880,220
VIII	4,899,949	1,906,900
Total	50,933,473	15,545,015

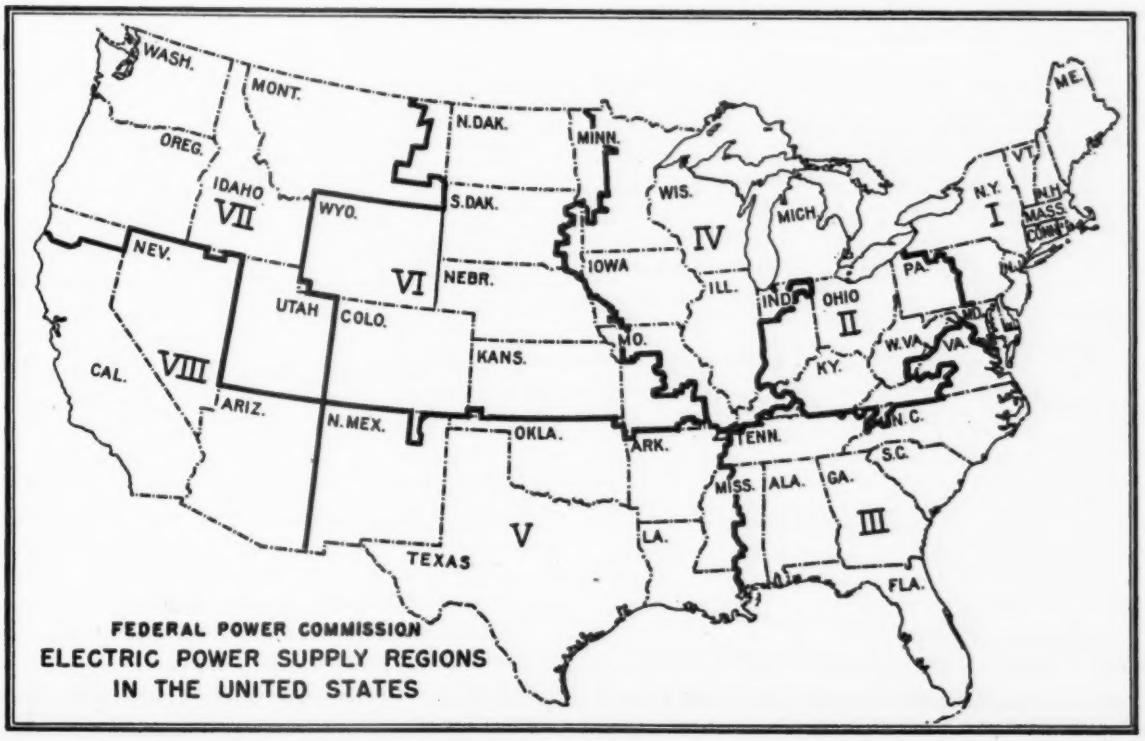
Geographically, as shown in Table 1, about 43 per cent of the total expansion in kilowatts is taking place in the Northeast and East Central states. This is as might be expected, inasmuch as approximately 46 per cent of the nation's capacity is already installed in these two sections of the country. However, although slightly less in kilowatt additions, the relative expansion in the East Central region is somewhat greater than that in the Northeast; but the South Central region leads in a *relative* expansion of 47 per cent over present capacity. This is in line with June 1948 figures for this section which showed a 20.3 per cent increase in energy consumption compared with June 1947 and a 17.8 per cent increase in peak demand. For the country as a whole, these figures were 12.2 and 10.8 per cent, respectively. The eight regions are indicated on the accompanying map.

A study of curves accompanying the report indicates that, although dependable capacity was safely above the June 1948 peak for the country as a whole, this was not so in some of the regions. Moreover, in several cases the net assured capacity (dependable less reserve) was considerably below the peak load, which is an unsatisfactory situation. However, additions completed thus far during the current year appear to have kept up with schedules and, barring further shortage of steel or other unforeseen circumstances, it is anticipated that future extension schedules will be maintained. Even so, they will leave little margin if the present rate of increase in demand keeps up.

If the combined figures for a number of interconnected systems in New Jersey and eastern Pennsylvania, as listed in the report, be excluded, the Consolidated Edison Company of New York leads both in present installed capacity and in 1951. Installed capacities of the six largest systems are as given in Table 2.

TABLE 2—CAPACITIES OF SIX LARGEST SYSTEMS

	As of June 30, 1948	End of 1951
Consolidated Edison Co. of N. Y.	2,731,800 kw	3,191,800 kw
T. V. A.	2,567,402 kw	3,038,800 kw
Commonwealth Edison (Chicago)	2,068,010 kw	2,625,000 kw
Niagara-Hudson System	1,682,266 kw	2,062,266 kw
Pacific Gas & Electric Co.	1,541,211 kw	2,694,611 kw
Bonneville Power Adm.	1,490,400 kw	2,138,400 kw



Early Developments in Pulverized Coal Firing—Part 2

By C. G. R. HUMPHREYS

Research Dept., Combustion Engineering Co.

In the September issue the author reviewed some of the early attempts at burning pulverized coal during the hundred years prior to 1913. The present article carries on over the succeeding ten years during which a number of pioneer installations were made culminating in successful commercial application and the rapid acceptance of this method of firing by the central station industry. Subsequent developments and applications over the last twenty-five years have been so diverse and extensive as to preclude inclusion in the present series. A third and concluding article in the November issue will discuss pulverized coal in the field of transportation.

THE curve in Fig. 1, reproduced from the 1923 N.E.L.A. Prime Movers Committee Report, shows an astonishing upsurge for 1918 in the application of pulverized coal for steam generation. Starting around 1895 this method of firing coal began to gain some following in certain industrial applications, such as for portland cement manufacture, as well as in forges and some other metallurgical work; but between 1900 and 1915 there are recorded only a few isolated cases of steam boilers being so equipped. These were more or less experimental and served to point out the obstacles that must be overcome before commercial success could be attained.

Table I, reproduced from A.S.M.E. *Transactions* of 1919, is from a paper by F. A. Scheffler and H. G. Barnhurst listing some of the plants of that period burning pulverized coal. Mention will be made of a few of these.

A much publicized installation was that at the locomotive shops of the Missouri, Kansas & Texas Railway at Parsons, Kans. This consisted of eight 250-hp box-header, water-tube boilers operating at 150 psi and having refractory furnaces. Lignite and slack coal were burned.

Initial operation pointed to the necessity for rather extensive alterations including substitution of vertical for horizontal baffles to overcome excessive ash accumulations. Also, spalling of the refractories and wall collapses indicated the inadequacy of existing furnace volume which was later increased to form a dutch oven. Firing was horizontal through the front wall as shown in Fig. 2 (reproduced from "Powdered Coal as Fuel," by C. F. Herington, 1920). Because of the high moisture content of the lignite it became necessary at times to pass it twice through the dryers. Reported tests showed efficiencies ranging from 53.6 to 73.6 per cent.

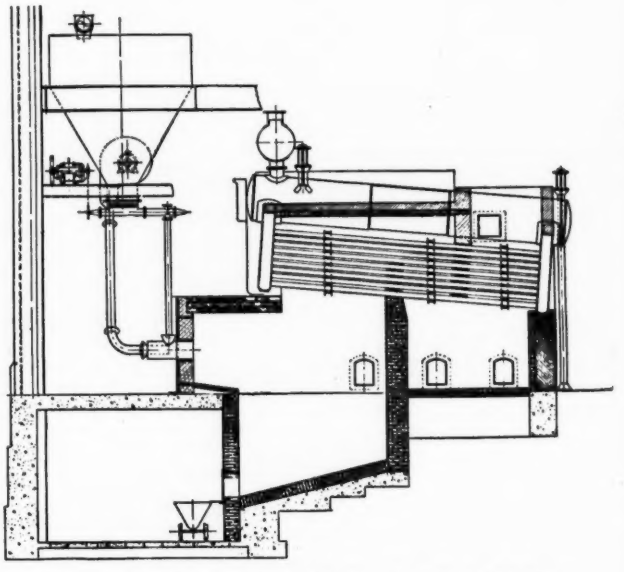


Fig. 2—Section through M. K. & T. R. R. Setting

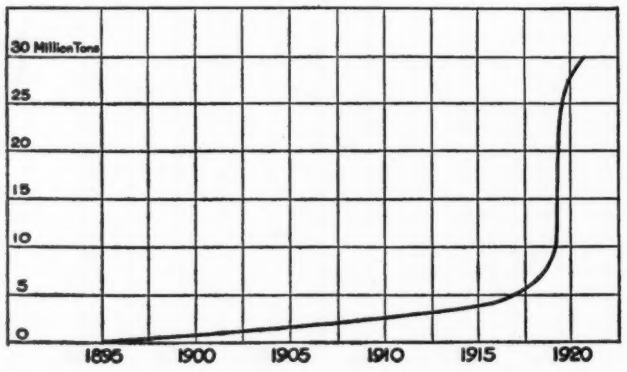


Fig. 1—Curve showing growth of pulverized coal in the United States, 1895–1921

However, as a result of increased price of coal and labor and more favorable oil price, this installation by 1920 had reverted to the burning of oil.

A most unusual arrangement was that at the Sizer Forge Company where ten reverberatory furnaces also supplied waste heat to five 250-hp boilers. Each unit of two heating furnaces and one boiler had three burners, so each boiler had means for supplying heat exclusive of the waste gases from the furnaces.

Reference is made in Table 1 to the Pacific Coast Coal Company, and it may be of interest to point out that this

Fig. 3—Delivering pulverized coal by tank wagon in Seattle

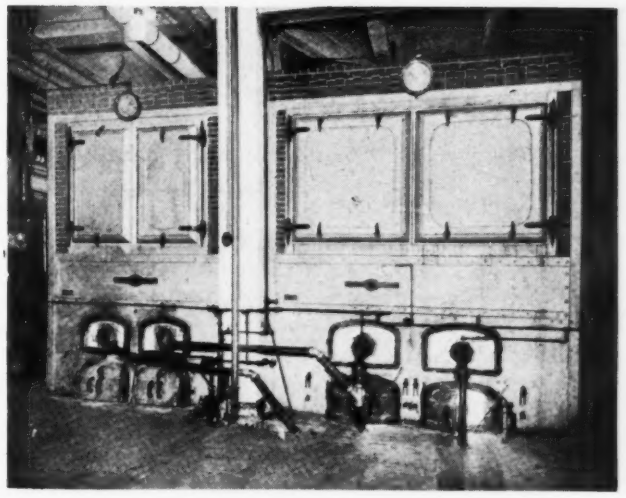


Fig. 4—Office building boiler plant using pulverized coal delivered by tank wagon

company was engaged actively in supplying coal by divers means. It owned a number of mines not far from Seattle and operated two central pulverizing plants which, in addition to supplying its own mine power plants, also furnished about 30 tons of pulverized coal per day for delivery to customers. It was a pioneer in this field of coal usage on the Pacific Coast. Pulverized coal was delivered to Seattle by tank cars and distributed locally by trucks to various buildings in the city. Figs. 3 and 4 taken from a pamphlet of the Canadian Conservation Commission by W. J. Dick, 1919, show, respectively, a truck delivering pulverized coal and the boiler room of one of the office buildings using this service.

The Puget Sound Traction, Light & Power Company included among its properties a steam heating plant, Western Avenue. Fuel costs were high and a large culm bank at near-by Renton Mine lay untouched. Consequently, the Company, early in 1917 contracted with the Pacific Coast Coal Company, to supply pulverized washings from the Washington lignite in the Renton coal dump, this method of firing having been tried out in an experimental installation under a 300-hp water-tube boiler as designed by E. B. Powell of Stone & Webster, consulting engineers for the Company and W. G. Santmyer of the Puget Sound organization.

Despite limited capacity due to slagging and refractory erosion and a test efficiency of only 71 per cent, the re-

TABLE I BOILER INSTALLATIONS USING PULVERIZED COAL

Date of Installation	Name of Company	Location	No. of Boilers	Horsepower Rating and Make of Boilers	Furnace Design, Per cent of Rating	Coal Used
Aug. 1916	M. K. & T. R. R.	Parsons, Kan.	8	250 O'Brien	125–150	McAllister Cherokee slack, Kan. semi-anthracite, Texas lignites, San Bois coal, Oklahoma
Nov. 1916	American Locomotive Co.	Schenectady, N. Y.	1	300 Franklin	150	
June 1918	U. S. Verde Extension Mining Co.	Verde, Ariz.	2	439 Stirling	150	Gallup and semi-lignite
Feb. 1918	Ash Grove Lime & Cement Co.	Chanute, Kan.	1	371 Heine	150	Various grades of Kansas coals
June 1918	Garfield Smelting Co.	Garfield, Utah	2	371 Stirling	150	Wyoming lignite, Wyopa, Wyoming lignite. Keystone, Utah, bituminous from various mines
Nov. 1918	Puget Sound Light and Power Co.	Seattle, Wash.	10	4-300 B. & W. 2-600 B. & W. 3-400 B. & W. 1-500 B. & W.	150	Renton buckwheat, Washington bituminous lignite and subbituminous
Nov. 1917	Sizer Forge Co.*	Buffalo, N. Y.	5	250 Rust	125	Pittsburgh and Pennsylvania
Mar. 1919	British Columbia Sugar Refinery Co.	Vancouver, B. C.	13	2-504 Badenhausen 2-250 B. & W. 9-110 HRT	150	Vancouver, B. C., bituminous and lignite
July 1918	Milwaukee Electric Railway & Light Co.	Milwaukee, Wis.	5	408 Edge Moor	150	Indiana and Illinois bituminous, Pittsburgh and Youghiogheny
Mar. 1919	Allegheny Steel Co.	Allegheny, Pa.	1	333 Wickes	...	Pittsburgh coals
June 1919	Inland Steel Co.	Chicago Heights, Ill.	1	250 Heine	150	Illinois bituminous
June 1918	Pacific Coast Coal Co.	Seattle, Wash.	10	150 HRT	...	Renton buckwheat
			8	100 HRT	...	Washington bituminous, lignite and sub-bituminous
Nov. 1918	Susquehanna Collieries Co.	Lykens, Pa.	1	250 B. & W.	200	All grades of anthracite washery culm, mine dirt, No. 3 buckwheat, Lykens slush, Lytle slush
June 1919	Lytle Coal Co.	Lytle, Pa.	6	333 B. & W.	200	All grades of anthracite, washery culm, Lytle slush
May 1919	Garfield Smelting Co. (2d installation)	Garfield, Utah	4	371 Stirling	150	Wyoming lignite, Wyopa, Wyoming lignite, Keystone, Utah, bituminous from various mines
Sept. 1918	L. S. Smith Bldg.	Seattle, Wash.	2	1-300 B. &. W. 1-200 B. & W.	...	Obtain and use coal from Pacific Coast Coal Co.
Sept. 1918	Crystal Natatorium	Seattle, Wash.	2	72 × 18 HRT	...	Obtain and use coal from Pacific Coast Coal Co.
Sept. 1918	Pacific Coast Coal Co.	Seattle, Wash.	12	2-250 Wickes 2-125 Ames (72 × 16) 6-125 handler & Taylor 2-125 Basey-Hedges	...	Obtain and use coal from Pacific Coast Coal Co.

* Also use some waste heat from pulverized-coal-fired furnaces.

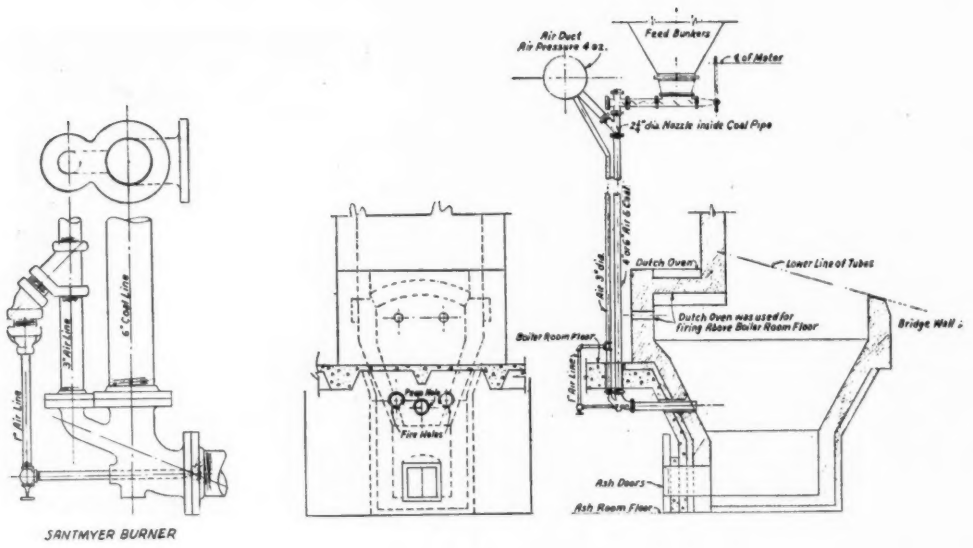


Fig. 5—Section through 600-hp unit at Western Avenue Station

sults with the experimental unit were sufficiently encouraging to warrant a decision to convert the existing nine boilers in the plant and one new 600-hp boiler (Fig. 5) to pulverized coal firing. Only with the new unit was it possible to provide the most desirable furnace arrangement. Unlike the experimental unit, fuel was supplied from pulverizers at the plant and dryers were provided as the sludge ran high in moisture. The dutch ovens, at first installed, were subsequently eliminated, partly because of difficulty in maintaining the arches, and horizontal burners were adopted. However, due to restricted furnace volume, furnace temperature was limited to about 2400 F at the bridgewall in order to avoid injuring the walls and accumulating fused ash in the pit; as a consequence of which the CO_2 was low. A 24-hr test on the 600-hp unit, run on February 1–2, 1919 and reported to the N.E.L.A. Prime Movers Committee, showed an efficiency 78.95 per cent, based on coal as fired. Reported operating results for the year 1921 showed a gross average boiler efficiency of 79.13 per cent.

Early Attempts to Burn Pulverized Anthracite

An interesting application of firing with pulverized anthracite silt was at the Lytle Coal Company late in 1918 where six boilers were so equipped. Originally a horizontal burner was employed and the coal injected beneath the arch; but, although the coal burned successfully, the ash fused, solidified and was removed only after drilling and blasting. The firing was changed to the arrangement shown in Fig. 6 (reproduced from Canadian Department of Mines bulletin by John Blizard, 1921), but it was found necessary to vary the flame length with the combustion rate, as it was most essential that combustion be completed before the flame entered the tube bank.

A precursor of applications with pulverized anthracite is inserted here as mentioned in the book *Combustion Engineering*, page 9–34: "During 1915 a boiler in the Oliphant Plant of the Hudson Coal Company was equipped to burn pulverized anthracite. The burners were of a horizontal type that had been previously developed for locomotive firing. They were placed in the front furnace wall. To maintain ignition, it was necessary to operate with at least 17 per cent CO_2. The furnace was small, and high temperature caused frequent refractory failures. This experiment was finally abandoned."

In May 1918 the first of several pulverized-coal-fired units at the Oneida Street electric power station of the Milwaukee Electric Railway & Light Company was placed in service. Fig. 7 shows the general arrangement of this unit. It is an illustration from one of the late John Anderson's original papers and does not include the improvised water screen used later by Henry Kreisinger and John Blizard. This was illustrated and described by B. J. Cross in his A.S.M.E. paper delivered at Milwaukee last June and reported in COMBUSTION, June 1948, page 36.

It is worth repetition here to include excerpts from the log of the official test on five Oneida Street units, Table 2, in which the U. S. Bureau of Mines cooperated.

Operation at Oneida Street with vertical burners instead of the then more common horizontal burners and with a larger than usual furnace volume eliminated certain operating difficulties. Nevertheless, high furnace

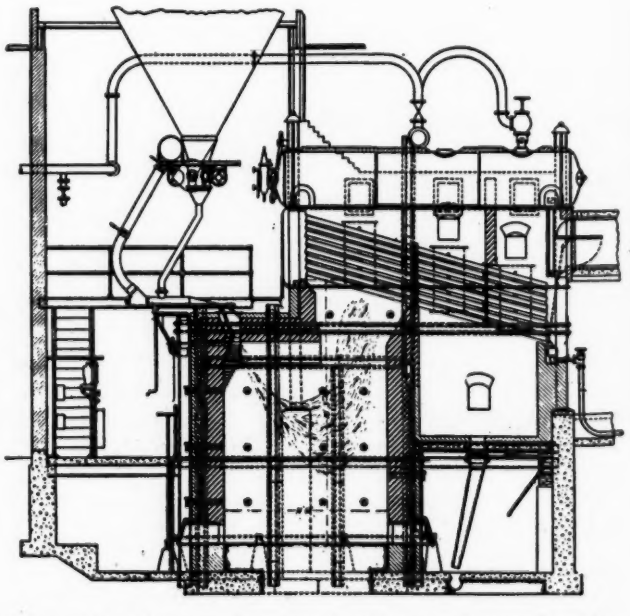


Fig. 6—Modified arrangement for firing pulverized anthracite at Lytle Coal Company plant

temperatures produced considerable slag formations and created problems for their removal.

While the Oneida Street installation appears to have been the first central *power* station to go to pulverized coal, the plant, like the others noted, was not initially laid out for this method of firing; they all represented conversions from other methods of firing. However, in the readjustment following the termination of World War I there arose a demand for more power which resulted in the planning of new stations. Advancing fuel and labor costs indicated the desirability of larger steam

TABLE 2—EXCERPTS FROM LOG OF TEST ON FIVE 486-HP BOILERS AT ONEIDA STREET

Duration of test, hours	99
Date of test	Nov. 11 to 15, 1919
Kind of coal	Mixture of Yough, and E. Kentucky screenings
Moisture in coal as received, per cent	7.23
Moisture in coal as fired, per cent	0.67
Ash in coal as fired, per cent	11.82
Volatile in coal as fired, per cent	34.40
Calorific value of coal, Btu per lb, dry	12,810
Steam pressure, psig	167.8
Steam temperature at s. o. outlet, F	441.9
Temperature of feedwater entering boiler, F	156.3
Temperature of flame above hearth, F	2767
Temperature at furnace bottoms, F	2180
CO_2 in flue gas, per cent	12.26
O in flue gases, per cent	6.82
CO in flue gas	None
Evaporation per hr, per boiler, f & a, lb	19,121
Per cent of rated capacity developed	118.4
Efficiency of boiler and furnace, per cent	80.67

Observations: The high percentage of excess air, together with a correspondingly low CO_2, was not determined by combustion considerations but rather by furnace limitations. No slagging occurred on the boiler tubes; flues were blown once every 8 hr, and slag was withdrawn from furnaces twice in 24 hr.

generating units of higher pressure instead of a multiplicity of smaller boilers, as before; and pulverized coal firing appeared ideally adapted to the new conditions. Experience gained over the preceding few years had pointed the way to successful design and this was especially true concerning the lessons learned at Milwaukee, with particular reference to such things as adequate combustion volume, the effects of flame impingement, the effect of a water-cooled screen, etc.

First New Pulverized-Coal-Fired Electric Generating Station

Based on this experience the Milwaukee Electric Railway & Light Company (now the Wisconsin Electric Power Company) proceeded in 1920 with the design of its new Lakeside Station—the first new central power station to be laid out completely for burning coal in pulverized form. In a brochure issued by the operating company describing this installation, the following statement appears:

"The decision to accept pulverized coal as the standard method of firing was prompted by the successful and encouraging results obtained in a trial installation at the Company's East Wells Street power plant.[1] Boiler efficiencies some four points higher than any on record had there been obtained with pulverized coal."

Fig. 8 is a section through one of the first eight Lakeside 1306-hp horizontal water-tube boilers which had air-cooled walls and water-cooled floor screens and radiant superheaters on the rear walls. Firing was by the Lopulco System such as had been employed at Oneida Street with vertical burners and secondary air through the front walls. The steam pressure of 315 psi was in line with advanced practice at that time and pulverizing was accomplished in a central preparation plant. The unit system of firing, now so widely employed, had not yet come into vogue. Initial operation was December 15, 1920, and in 1923 eight additional boilers were added, making sixteen in all.

Incidentally, when this station was laid down there were some skeptics who predicted that the screen tubes would burn up, while others insisted that the cold surfaces would hinder combustion and produce heavy smoke. Neither of these difficulties was encountered and this indicated the probable success of completely water-cooled furnaces which, when later introduced at this and other plants, encountered the same false predictions.

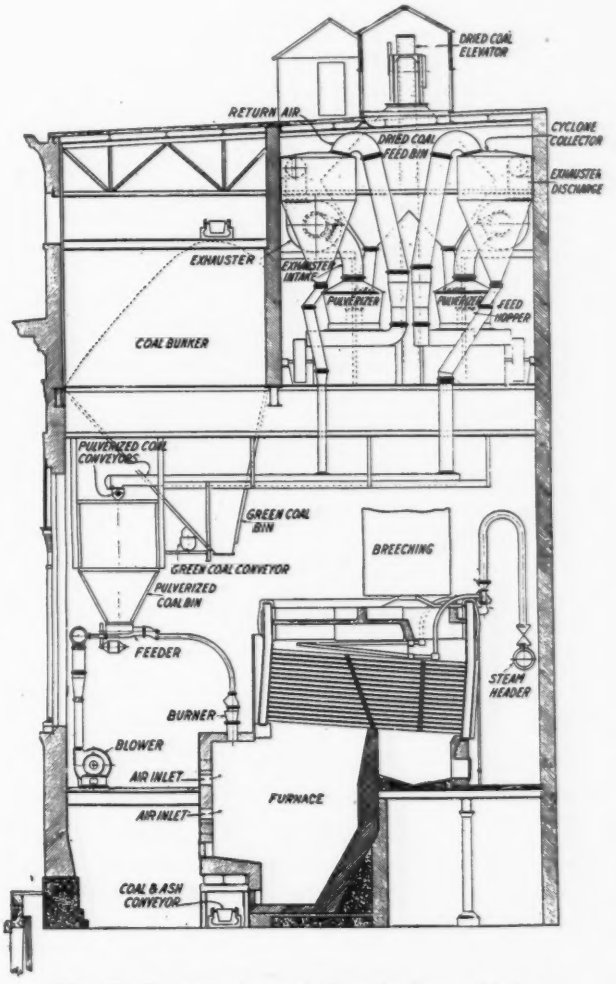


Fig. 7—Section through Oneida Street boiler

A summary of overall performance at Lakeside as reported to the N.E.L.A. Prime Movers Committee for the first six months of 1923 showed average boiler efficiency during steaming periods to be 82.18 per cent and average ratings 151 per cent. During the last six months of that year the average boiler efficiency during steaming periods was 85.78 per cent, and the average boiler rating 201.8 per cent.

Contemporary with this first large new central station to employ pulverized coal completely was an outstanding industrial plant—the Ford Motor Company at River Rouge. Here the initial installation consisted of four 200,000-lb per hr multi-drum, bent-tube boilers fired by the system employed at Lakeside. Fig. 9 is a section through one of these units.

[1] Otherwise known as Oneida Street.

The fact that these were at that time the world's largest steam generating units attests to the confidence which that company's engineers and its management held in the success of pulverized coal. Three years later, in 1923, four additional units, duplicates of the first, were added. Later, the original units were remodeled to produce 500,000-lb per hr capacity and fin-type water-cooled walls were added. Through subsequent additions

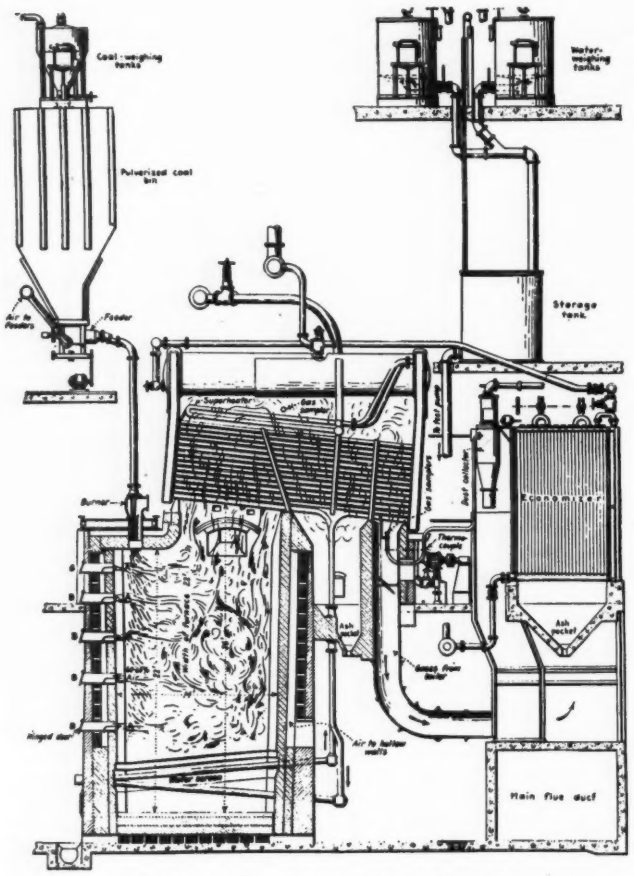


Fig. 8—Section through one of first Lakeside units

of still larger units which employ high pressure, high temperature and tangential firing, the Rouge Plant still retains the distinction of being the world's largest industrial power plant.

It was apparent by the success of these installations that pulverized coal had come to stay and the next two or three years saw a large number of new central stations employing this method of firing and incorporating the results of earlier experience. To quote from the 1924 Prime Movers Report, that Committee observed:

"As a stamp of approval that such a plant is both efficient and reliable, it is necessary only to refer to the number of large companies which are either planning, building or operating central stations of large capacity using pulverized coal exclusively."

One might quote further from a 1921 report by E. B. Powell that "The possibilities offered by pulverized coal—continuously high thermal efficiency, flexibility of furnace control, almost complete elimination of banking loss, and utilization of otherwise waste fuels—all of which have had ample practical demonstration, must now be seriously considered in the design of any future steam plant of importance."

To mention only a few such plants laid down at that time, there were Colfax Station of the Duquesne Light Company, Cahokia Station at East St. Louis, Trenton Channel Station of the Detroit Edison Company, Springdale Station of the West Penn Power Company, Manchester Street Station at Providence and Lake Shore Station at Cleveland. In all, some fifteen large central stations had adopted pulverized coal in this country by 1923 or 1924.

European engineering journals of that time were frank in admitting that leadership in the field of pulverized coal applications was to be found in the United States.

In the early development period most of the experimental installations were in industrial power plants, but the widespread adoption of pulverized coal by the central station industry, beginning in the early 20's and following through the subsequent years, opened up broad opportunities for refinements in equipment and practice, the results of which were also applied extensively to large and medium-size industrial power installations.

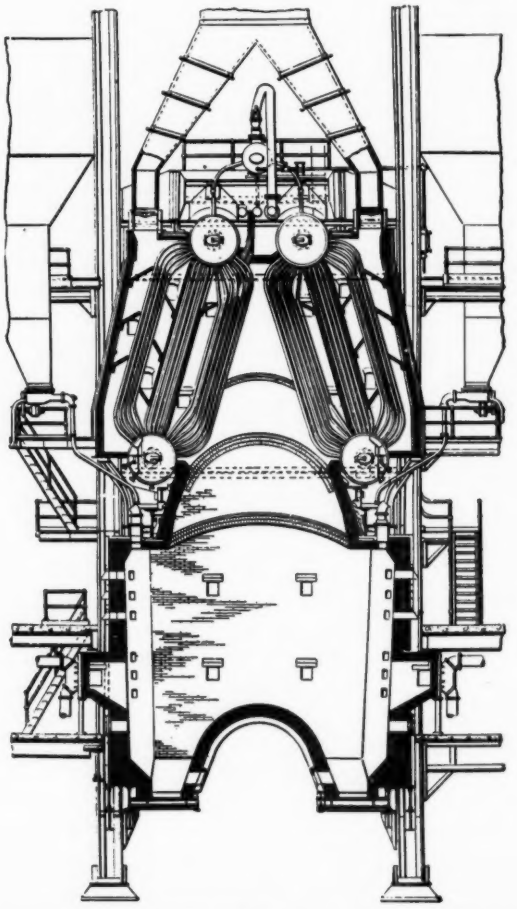
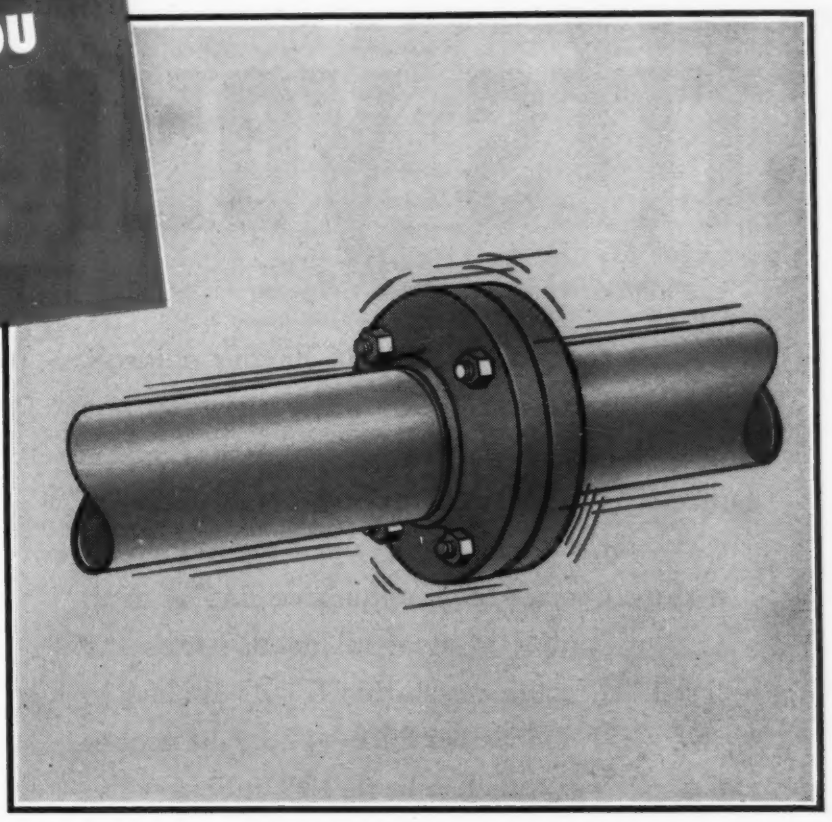


Fig. 9—One of initial 200,000-lb per hr units at River Rouge Plant of Ford Motor Company

In reviewing the pioneer work that made commercial large-scale application of pulverized coal possible in the early '20's, credit belongs to many individuals, but it is believed that had it not been for the foresight and boldness of John Anderson and the technical contributions to its development by such as Henry Kreisinger and his associates, the general application of pulverized coal might have been delayed several years.

How would you insulate this steam line?



A newly installed line carrying steam at 650° F. is subject to severe vibration from near-by traffic. Because of the high temperatures in the line, it should be insulated as soon as possible. On flanges the insulation must be removable. Which of these materials would you select?

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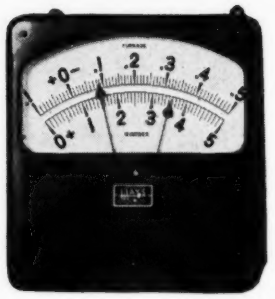

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Series D
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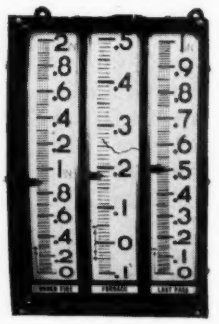

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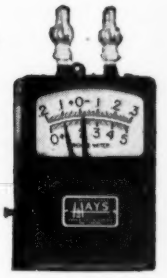

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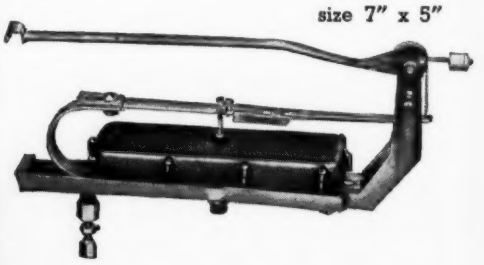
size 7" x 5"



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THE GENERAL FUEL SITUATION

By CARL E. MILLER

Technical Advisor, Battelle Memorial Institute

These notes are from a talk before the American Ceramic Society, September 9–10, 1948, and deal with the latest revised estimates on coal, oil and gas reserves. Those portions of the paper dealing specifically with the firing of refractories have been here omitted as not of general interest to power engineers. The author's conclusions, based on proved reserves and present rates of consumption, point to coal sufficient for nearly 2000 yr, natural gas for 30 yr and oil 12 yr, the last-mentioned figure possibly being extended by discovery of new sources of supply.

TAKING the fuels picture as a whole, the United States is obviously in a particularly fortunate position in that it has enormous reserves of coal and very substantial reserves of oil and gas. A conservative analysis of these reserves and our present rate of consumption would indicate that we have enough fuel for our national economy for many hundreds of years.

Undoubtedly we shall have shortages, but these will be due principally to necessary readjustments in our fuel economy. In fact, the many current and periodic shortages of oil, gasoline, gas, and coal constitute one of the many urgent reasons why, since V-J Day, not only the engineers, but the general public as well, have become increasingly interested in the subject of fuels. Another important reason is related to rumors concerning the possible effect on our fuel resources of international complications. The main question is: Would we be self-sufficient in time of an emergency under the present conditions of our fuel reserves? It is safe to say that we are in a better position than any foreign country. Although exact data are not available, it is estimated that we have from 40 to 50 per cent of the world reserve of all ranks of coals, and about 35 per cent of the proved world reserve of petroleum. A situation further stimulating interest in the subject of fuels has been a steady rise in prices, which has caused many to wonder what the final leveling-off point will be.

Coal Reserves

The extent of solid fuel reserves is estimated from geological observations and measurements of thickness and extent of deposits obtained from surface out-croppings, trenching and exploratory tunnels, shafts and drill cores. Great accuracy cannot be claimed for estimates so obtained, but, on the other hand, future exploration is not likely to add materially to these estimates. In fact, since the paper by A. C. Feildner, of the U. S. Bureau of Mines, on "Fuel Reserves" was delivered before the Annual Meeting of the American Society of Mechanical Engineers in 1946, subsequent information

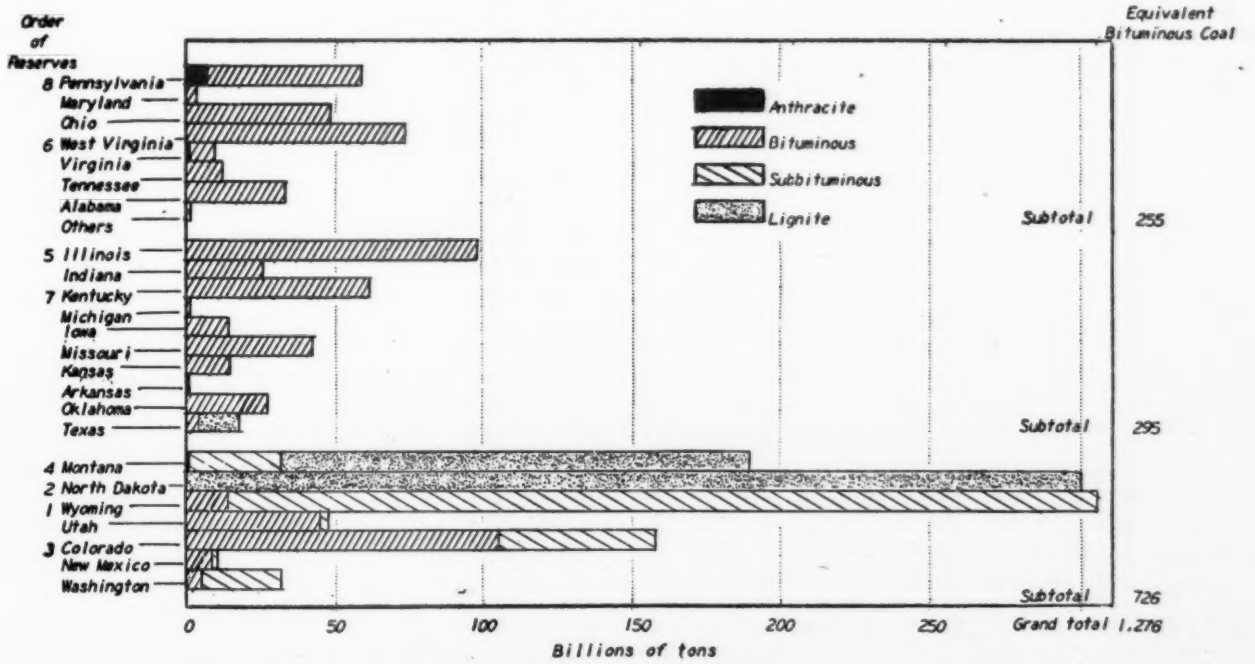

Fig. 1—Estimated Coal Reserves of United States, Jan. 1, 1948

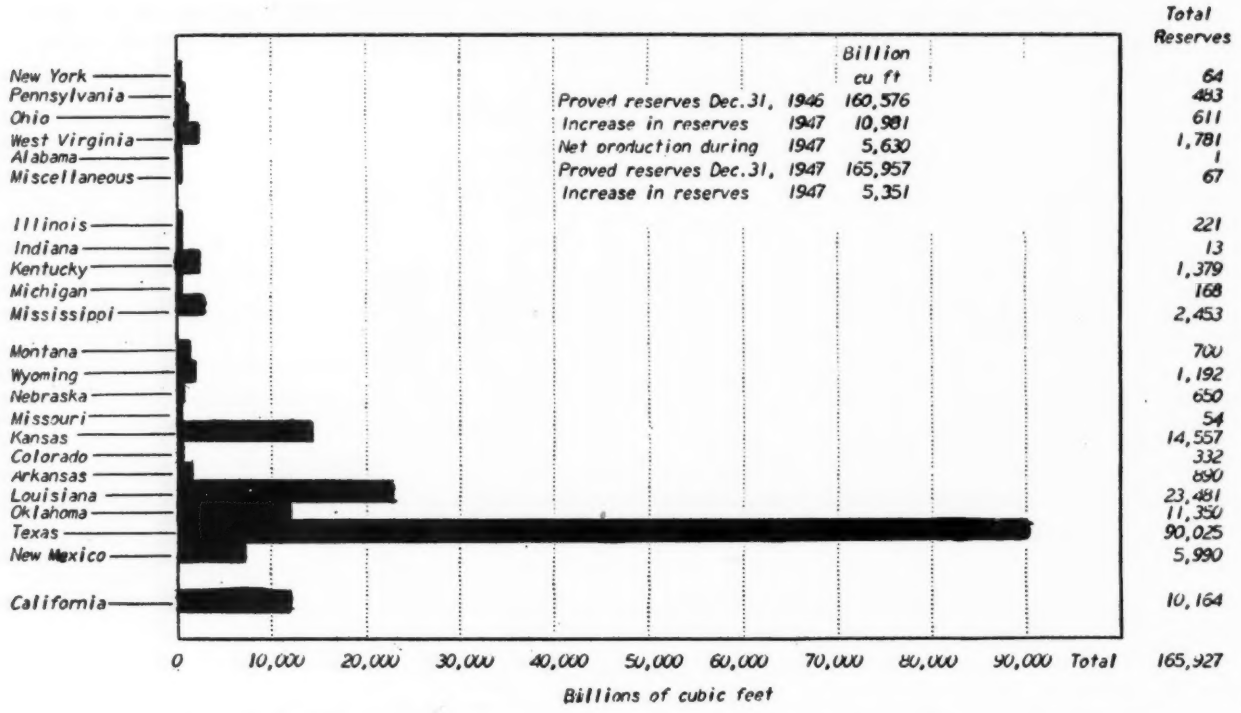

Fig. 2—Estimated Proved Recoverable Reserves of Natural Gas in the United States, Dec. 31, 1947

has resulted in a substantial lowering of the estimate of reserves reported at that time. There has been so much controversy about the actual extent of our coal reserves that, even now, plans are under way to obtain funds from Congress for making a more accurate determination of the extent of our coal deposits; that is, data on the quality, thickness of seams, the area and the depth below the surface.

Although future exploration probably will not discover additional deposits of any substantial amount, there is a real possibility that new techniques, such as improved types of mining machinery, or underground gasification, or both, may make it possible to use many coal deposits which are too thin or of too low a grade to mine under present conditions. Despite many conflicting stories concerning the exact amount of coal reserves available, everyone agrees that enormous deposits are available in this country and will be for many years.

Fig. 1 shows the location, quantity and quality of the major coal deposits.[1] It is obvious that the greater part of our reserves is in the West, and for all practical purposes this area is virtually untouched in so far as development is concerned. This lack of development in the western coal fields is due to two factors: (1) The demand for coal is greatest in the highly concentrated industrial area of the East and it is logical that the coal should be mined as close to the point of consumption as possible; and (2) the rank of eastern coals is considerably higher and more adaptable to present combustion equipment than are the western fuels, and, in general, the western coals do not lend themselves too well to transportation over long distances. The western deposits are largely classified as sub-bituminous and lignite coals and many of these have higher ash and moisture content than the eastern bituminous coals. Also most of the western coals have a lower heating value. It is customary to think of lignite as having a heating value of about 6700 Btu per lb, while sub-bituminous coal has 9500 Btu per lb, as compared to an average of 13,500 for eastern bituminous coal. It is natural that one should want to use the best coals first, but the fact should nevertheless be borne in mind that ultimately these low-rank coals must be used, and at such time it is quite certain they will be found to be very practical fuels if combustion equipment is properly designed for burning them.

The actual tonnage figure shown in Fig. 1, namely, 1276 billion tons, represents the equivalent tonnage of our reserves when all have been divided by approximately two, to convert one ton of lignite having a content of 6700 Btu per lb, to one ton of standard coal having a Btu content of 13,000 Btu per lb. The present rate of consumption of coal is between 650 and 700 million tons per year, and at this rate of consumption the reserves would be sufficient for nearly 2000 years.

Natural Gas Reserves

The estimates of reserves of gaseous and liquid fuels have been increased each year by new discoveries and extensions of existing fields, despite the increased yearly withdrawals. This is in definite contrast to the estimates of the reserves of coal, which are relatively static, and, if anything, are declining somewhat from year to year as more accurate information is obtained.

In reporting liquid or gaseous reserves, only *proved* reserves are given. Fig. 2[2] shows the location and quan-

[1] Based on statement of W. E. Wrather, Director U. S. Geological Survey: Hearings on Synthetic Liquid Fuels before a Subcommittee of the Committee on Public Lands and Surveys, U. S. Senate, 78th Congress, 1st Session, 1943, p. 98. Original data have been corrected to agree with 1948 Reserves Statement of Dr. Fieldner, Bureau of Mines, and are approximately one-half the 1943 estimates.

[2] Reports on "Proved Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas," Dec. 31, 1947. Published jointly by American Gas Association and American Petroleum Institute.

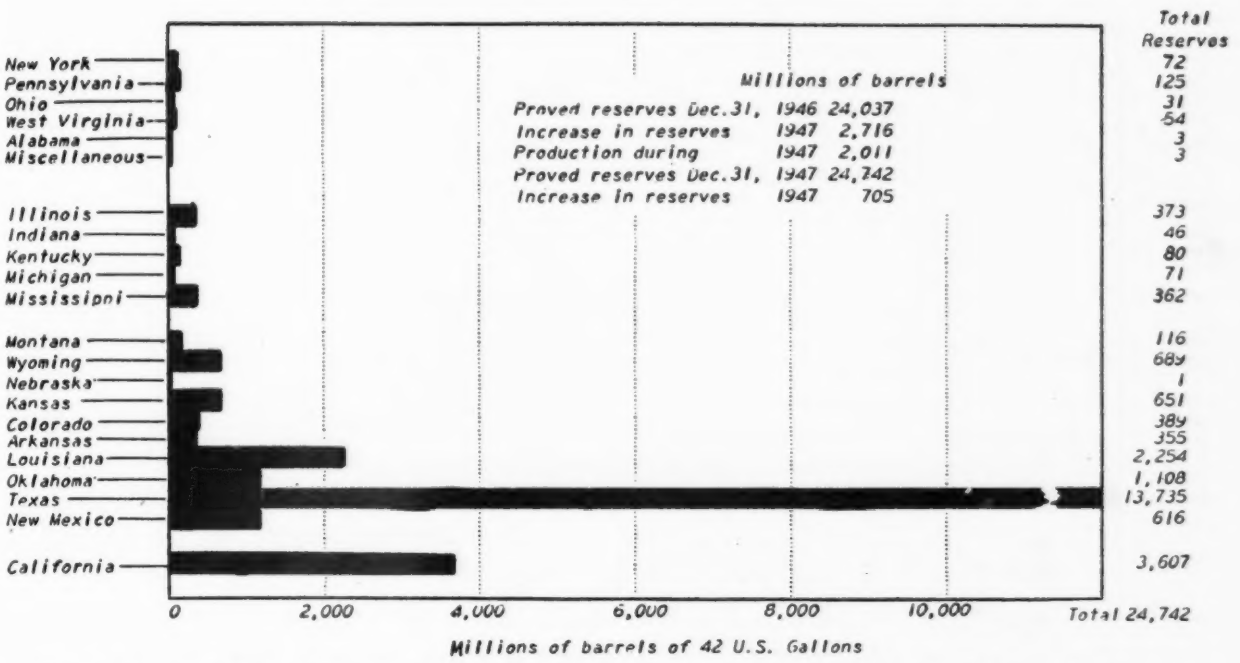

Fig. 3—Estimated Proved Reserves of Petroleum and Natural Gas Liquids in the United States, Dec. 31, 1947

tity of estimated proved recoverable reserves of natural gas in the United States as of December 31, 1947. The substantial reserves of gaseous fuel are in the Southwest: Texas, Louisiana, Kansas, Oklahoma, New Mexico and California. The production and distribution costs of gaseous fuel are low and the fuel is ideally clean and easy to burn in an efficient manner.

However, although there is an adequate supply for a substantial number of years, our gaseous-fuel resources are definitely limited. On the basis of the proved reserves of 165 trillion cubic feet, and last year's production of 5.63 trillion cubic feet, there would be enough for about 30 years. This estimate could possibly be doubled, and still be within reasonable accuracy, inasmuch as additional reserves are continually being found.

Oil Reserves

The subject of liquid-fuel reserves is the one which has been receiving most attention, and rightly so, because it is the reserves that undoubtedly will be depleted first. Fig. 3[2] shows the location and quantity of the estimated proved reserves of petroleum and natural-gas liquids in the United States as of December 31, 1947.

Our principal reserves of liquid fuel are in the Southwest, as are those of the gaseous fuels. The greatest reserve is in Texas, which has more than 50 per cent of the total for the entire country. Dividing the total proved reserves of 24.7 billion barrels by last year's consumption of slightly over 2 billion barrels gives an estimated life of our proved liquid-fuel reserves of about 12 years. However, since new reserves continue to be discovered and extensions made to existing ones, it might be reasonable to assume, that despite increasing demands, there may be sufficient total reserves in the United States to last 20 to 25 years.

Certainly, in some foreseeable future time it will be necessary to find new sources for oil and gasoline. The major oil companies are cognizant of this fact and are planning their programs on a basis that would lead us to believe that, excluding an emergency, the demands of our economy for gas and oil will be met.

Some of the plans on which work is being done to maintain a constant supply of liquid fuels are: (1) The supplementing of local reserves with imports from the more recently discovered oil fields of South America and the Middle East. This plan is economically feasible for supplying the demands of our peace-time economy, but it is impracticable as a source of supply in case of national emergency. (2) The use of synthetic conversion of gaseous fuel to liquid fuel. One plant of the conversion type is now being erected in order to study the technical and economic aspects of this method. Another was projected, but it has been announced only in the last few weeks that the plans have been suspended because of the rapid rise in the costs of plant construction. (3) Research is in progress and pilot plants are now being erected to convert coal to gas and to synthesize this gas for the manufacture of gasoline and fuel oil. Most of this work is being done by the Office of Synthetic Liquid Fuels of the Bureau of Mines, Department of the Interior. For a long-range plan, this procedure for making fuels seems very practicable. (4) Research is also being done and a pilot plant is being erected to determine the technical and economic practicability of extracting oil from a particular type of shale found in the Colorado region. This method of supplementing fuel supplies in many ways offers the greatest possibilities of any under consideration at the present time. It has the potentiality of being accomplished at a reasonable cost; it does not use up other fuel reserves; and does not waste a large part in the efficient synthetic conversion process currently available.

Table 1 shows the estimates of cost of gasoline made from these various sources. One point should not be lost sight of in looking over these costs or any costs on synthetic methods of making liquid fuel: Regardless of the method, tremendous capital investments are re-

TABLE I—COST OF SYNTHETIC FUELS

Comparative costs for gasoline from various sources (est.)

	Crude Oil	Natural Gas	Coal*	Oil Shale
Daily Capacity, barrels total products	60,000	9,500	14,000	10,000
Investments, $/bbl/day:				
For max distillate yield	4,300	7,400	7,600	6,100
For max gasoline yield	6,500	8,200	8,500	8,400
Possible housing investment (max gasoline case)	.....	....	2,900	900
Steel requirements, tons/bbl/day:				
For max distillate yield	5.7†	7.1	4.6	5.7
For max gasoline yield	7.8	7.9	5.2	7.4
Percentage gasoline in liquid products (max gasoline case)	87	90	89	87
Raw material price assumed or est.	$2.78/bbl‡	10c/mcf‡	$3.20/ton	$1/ton
Gasoline costs (max gasoline case), c/gal.:				
Raw material	8.8†	2.9†	3.9	4.2
Mfg. less credits	4.3	8.9	12.7	11.8
Product transp.	1.0	1.0	.....	....
Total	14.1†	12.8†	16.6	16.0
Added housing cost if required	.....	....	1.9	0.6
Effect of increase in raw-material cost	$1/bbl adds 3.2c/gal	10c/mcf adds 2.9c/gal	$1/ton adds 1.2c/gal	$1/ton adds 4.2c/gal
Effect of 10 per cent return on investment in mfg.	1.6c/gal	3.7c/gal	.....	.....
Or mfg. plus mining	.....	....	5.6c/gal	5.5c/gal

* In the East, by gasification.

† Includes steel for pipe line from refinery in Southwest to Eastern markets.

‡ These figures are based on crude oil and natural-gas prices, not on their costs. Data: Statement by E. V. Murphree, Standard Oil Development Co., to Oil Subcommittee of House Armed Service Committee, February 25, 1948. Costs include 5 per cent for amortization and 10 per cent return on investments involved.

quired, and this will be reflected in costs for synthetic liquid fuel higher than for petroleum products. Estimates of the cost of synthetic fuels have varied from 20 to 100 per cent more than the costs of fuel from petroleum.

Summary of Fuel Reserves

Table 2 summarizes the entire fuel-reserve situation for coal, gas, oil and oil shale. Inasmuch as the basic source of this information has been shown on the previous charts, it needs no further explanation.

If one has been following some of the previously published data on coal reserves which have shown from 2.5 trillion to 3.1 trillion net tons of reserve, some explanation may be in order for the indicated figures of 1.6 trillion net tons of reserve. This reduction stems from two factors: (1) A mining loss of about 30 per cent has been included in the figure shown on this table. This method of representation appears to be more realistic than that used in previously published tables that included the loss as a deduction in the final calculations. (2) A general reduction of about 20 per cent in the reserve figures themselves has been made in order to place these data on a more accurate basis.

By equating all fuel reserves to equivalent tons of 13,000-Btu coal, it is found that the total reserves of petroleum are 5.7 billion net tons, oil from shale 21.2 billion net tons, natural gas 6.4 billion net tons and coal itself 1276 billion net tons. Present yearly rates of consumption for the three fuels are: Petroleum, 0.46 billion net tons; gas, 0.22 billion net tons; and coal, 0.69 billion net tons, making a total annual consumption of 1.37 billion net tons. In terms of supplying our present consumption of heat energy from the various reserves indicated, this would mean that we have a total reserve of equivalent heat units sufficient for our needs for about one thousand years.

Possibly this consumption versus reserve picture can be represented a little better by the use of two other charts. Fig. 4 shows, percentagewise, our estimated proportion of consumption of fuels in the United States based on 1947 figures; these are, coal 51 per cent, petroleum 33 per cent and gas 16 per cent. Fig. 5 shows the various percentages of estimated mineral reserves as of January 1, 1948. Note that in so far as percentages of total reserves are concerned, proved petroleum reserves are 0.4 per cent, gas reserves are 0.5 per cent, oil-shale reserves are 1.6 per cent and coal reserves are 97.5 per cent of the total. These two charts indicate, better than words can express, the fact that new problems must be faced in the general fuels situation.

Summary

To summarize the general fuel situation, the following points seem to be most pertinent:

1. The gaseous-fuel reserves in this country are ample for our immediate needs. The increasing pressure to use this fuel for special industrial purposes and domestic requirements indicates that in many cases industry will

TABLE 2—ESTIMATED MINERAL-FUEL RESERVES OF THE UNITED STATES, JANUARY 1, 1948

Description	Reserve Jan. 1, 1948	Assumed Annual Production	Equivalent Billions of Net Tons —Bituminous Coal (a) 13,000 Btu per Lb— Reserve Jan. 1, 1948	Fraction of Total Fuel Reserves, %	Assumed Annual Production	Reserve Divided by Annual Production
Coal, billions of net tons:						
Anthracite	7.5	0.060	7.3	0.6	0.06	162
Bituminous coal	700	0.600	728	55.6	0.62	895
Subbituminous coal	409	0.014	299	22.8	0.01	....
Lignite	470	0.004	242	18.5	0.002	....
Total	1586.55 (b)	0.678	1276	97.5	0.69	1850
Petroleum and natural gas liquids, billions of barrels	24.7	2.0	5.7	0.4	0.46	12.7
Oil from oil shale, billions of barrels	92 (b)	2.0	21.2	1.6	(0.46)	46.1
Natural gas, trillions of cubic feet	165.9	5.6	6.4	0.5	0.22	29.1
TOTAL all fuels	.....	...	1309	..	1.37	955

(a) Heating values used: Anthracite.....12,900 Btu per lb; Bituminous coal.....13,500 Btu per lb; Sub-bituminous.....9,500 Btu per lb; Petroleum and nat.-gas liquids...6,000,000 Btu per bbl; Lignite.....6,700 Btu per lb; Natural gas.....1,000 Btu per cu ft

(b) Data from Dr. A. C. Fieldner, Chief, Fuels and Explosives Branch, Bureau of Mines, corrected to January 1, 1948.

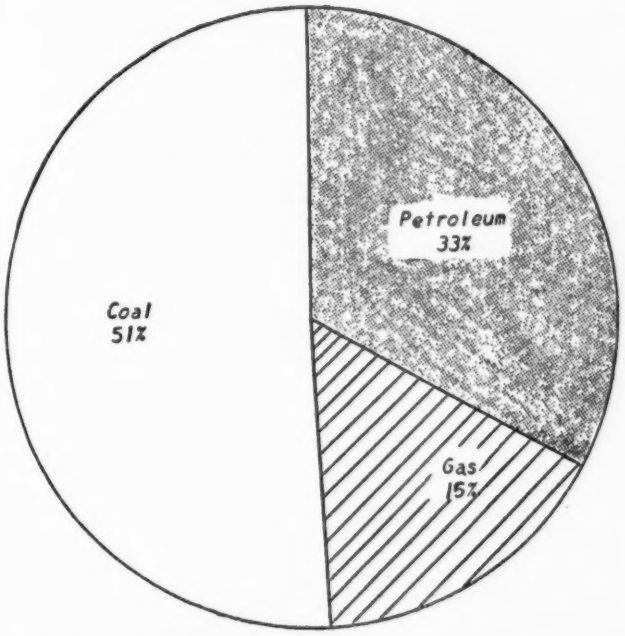

Fig. 4—Estimated Proportion of Consumption of Fuel in the United States, Jan. 1, 1948

be required to provide standby facilities if it is to operate on a year-round basis without interruptions.

2. The supply of liquid-fuel reserves is limited when we consider proved petroleum reserve by itself. Steps are being taken to supplement the deficiency of crude petroleum by the use of oil from shale, or by the synthesis of liquid fuel from either gas or coal.

3. Liquid-fuel prices at the present time are high, and as more and more synthetic methods or foreign sources of crude oil are used, the price will go even higher; that is, the differential between the use of oil as compared to other fuels available in this country will doubtless increase as time goes on.

4. Coal reserves of this country are, for all intents and purposes, practically unlimited.

Coal, therefore, would seem to be the fuel which should be chosen for sound, long-range planning, if it can be utilized in a particular manufacturing process through proper choice of equipment. Then, although problems in fuel supply arise in the future as they have in the past, our continuity and cost of production will be more apt to be able to compete favorably with other methods because we have based our plans on a fuel supply which is within this country and which is practically unlimited reserve.

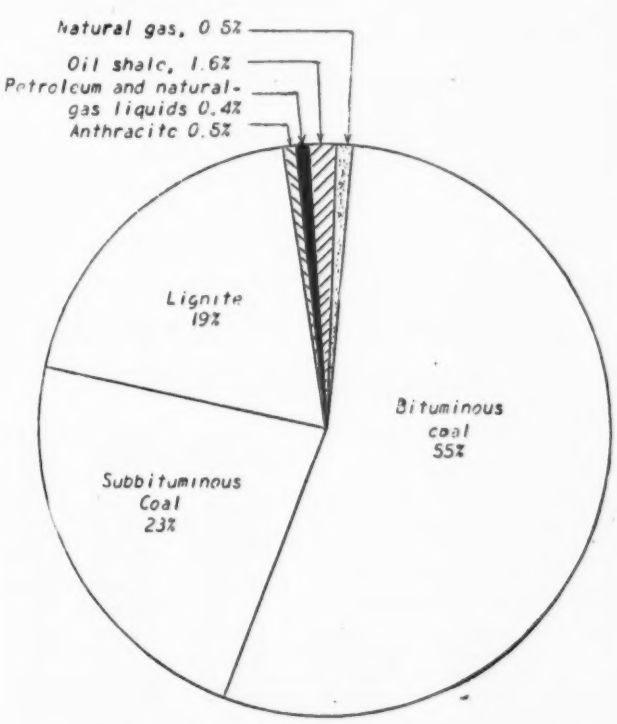

Fig. 5—Estimated Mineral Reserves of the United States, Jan. 1, 1948

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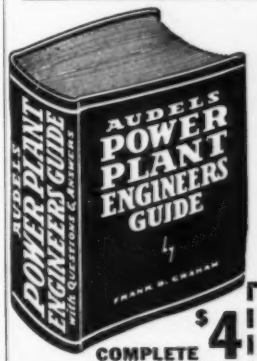

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Steam Generator Development to Obtain High Availability*

By W. J. VOGEL
Executive Engineer,
Combustion Engineering Co.

DEVELOPMENT of the steam generator over the past twenty-five years has been directly influenced by station thermal heat balance. Other factors have been the development and research work carried on by both manufacturer and user. Metallurgy has also kept pace, permitting the trend to higher pressures and temperatures. The continual improvement in welding technique has made possible heavy-wall drums for the increasing pressures; welding of tubes eliminated objectionable intermediate water-wall headers within the furnace, and the welding together of piping and fittings removed the problems of bolted connections. The specialist in feedwater conditioning met problems encountered with increasing pressures. Basic performance data were accumulated. The result today is a steam generator with an availability factor equivalent to that of the turbine.

The trend in turbine design to units of higher capacity necessitated increasing the size of the steam generator. When the first large-capacity, high-pressure and high-temperature steam generators were placed in operation difficulties encountered were of the same general pattern. They included high furnace exit gas temperatures which produced slagging over of the heat-absorbing surfaces; steam output was reduced; efficiencies were lowered; and outages became necessary for deslagging. The depreciation in coal quality served to aggravate the situation. In this era the tendency was to arrange the heat-absorbing surfaces in compact units to reduce cost. High absorption rates were expected from high gas velocities; but the combination of high gas temperatures and high gas velocities resulted in slagging. Much basic data were obtained in this period and such information indicated that furnaces should be increased in size and also that the heat-absorbing surfaces should be opened up to permit lower gas velocities over these surfaces.

Accumulation of furnace performance data indicated that the valuation of furnace heat absorption efficiency depended upon the type of fuel burners, their location in the furnace, the type of furnace wall construction and the shape of the furnace envelope. It was noted that furnace heat absorption varied with load changes, variation of furnace excess air and from slag or ash accumulations on the furnace walls. For any given furnace, as load increases, the heat input increases, but the rate of heat absorption does not increase as rapidly as the rate of heat input; therefore, the furnace leaving temperature will rise. Each of the various types of fixed burners has a characteristic heat absorption curve. The amount of heat absorbed will vary with excess air and ash formations on the wall surfaces and location of the burners in the furnace.

If the designer were given the condition of obtaining the desired steam temperature at continuous load only, the problem would be relatively easy, as variations in furnace exit gas temperature could be

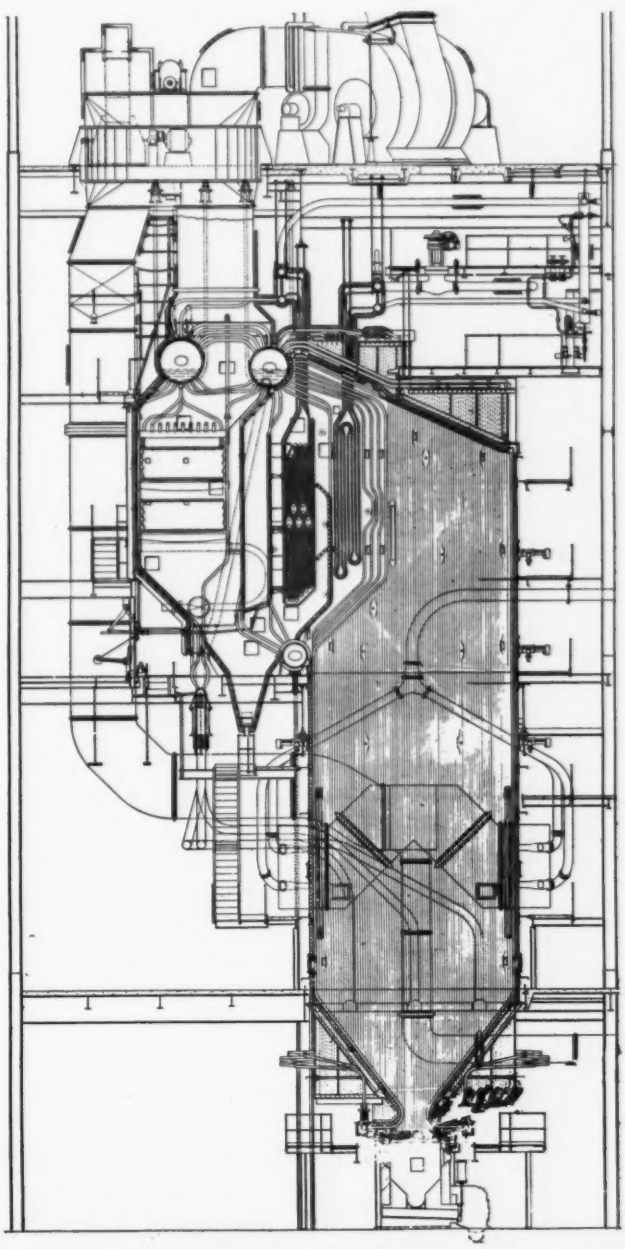


Fig. 1—Section through Tidd unit

* From a talk before the Southeast Electrical Exchange at Asheville, N. C., September 17, 1948.

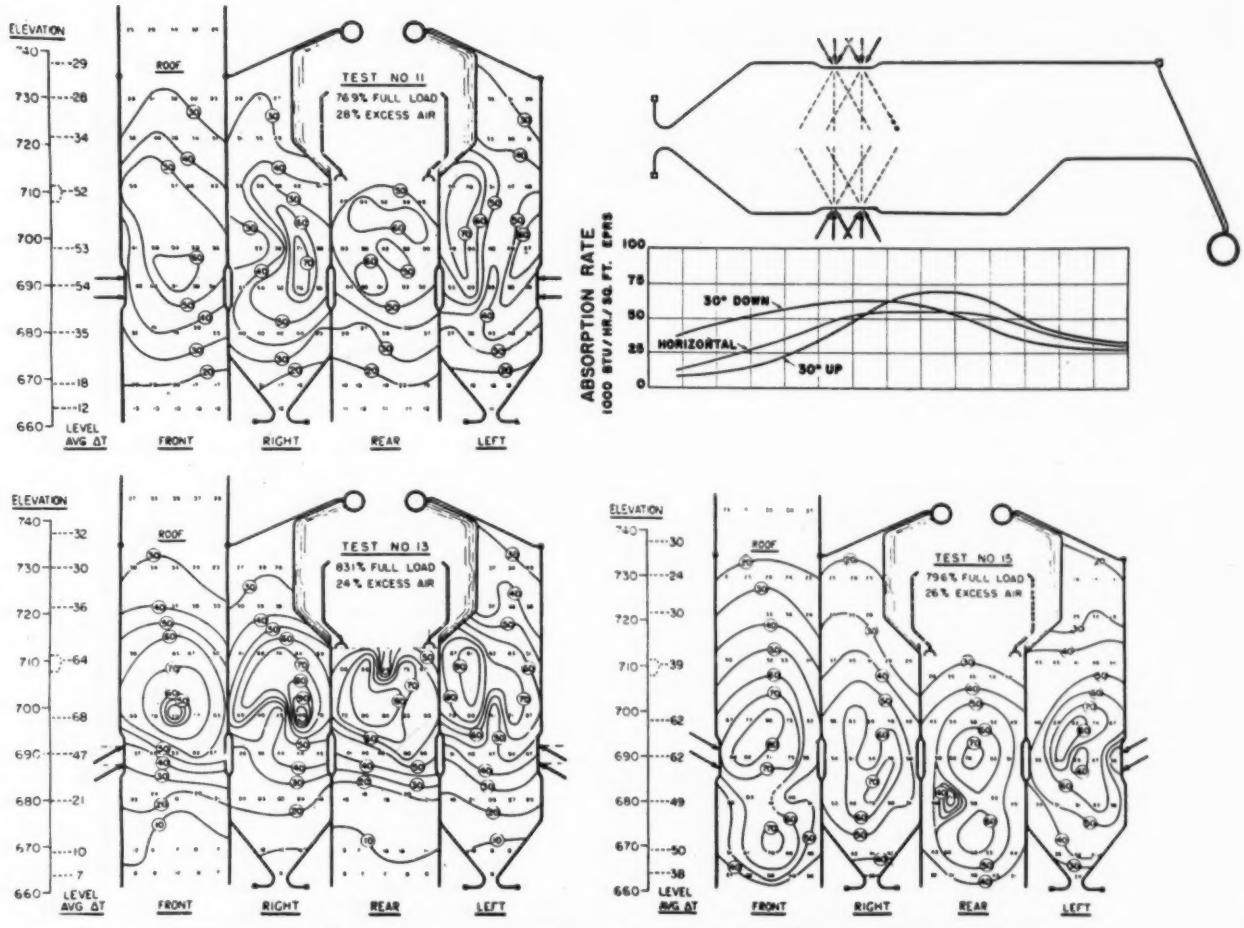


Fig. 2—Results of tests showing heat absorption for different burner positions

maintained reasonably well within workable limits. But specifications generally request that steam temperatures be maintained from some partial load point to maximum design load. Hence, there must be sufficient superheater surface to produce the steam temperature at partial load. The superheater is the most costly single item of the steam generator. It is essential, therefore, to arrange this surface economically. For the determined amount of superheater surface, there is required a definite entering gas temperature. As the steam rate increases above partial load point, the gas temperature will also rise. Therefore, steam temperature must be controlled either by gas bypass damper, by desuperheaters or some other means. When using a bypass damper or desuperheater arrangements for steam temperature control, the furnace exit gas temperature at top load will be higher than actually required by the superheater. It is this range of gas temperature above that required at top load, which, with fixed burners, may be above the ash fusion temperature of the coal in use and ash deposits on the surface will occur.

The company with which the author is associated started work in 1940 to develop a means of controlling furnace exit gas temperature. One of our fixed type burner designs in use at the time was the tangential burner. These burners are located in each furnace corner and the stream of fuel and air from each burner strikes the stream immediately preceding it, so that a spiral path of flame results through the furnace. This type of firing produces the greatest turbulence of the gas streams within the furnace and a positive direction of coal and air, with the result that combustion is completed lower down in the furnace. The fuel and air are directed in horizontal streams tangent to an imaginary circle at the center of the furnace. In an attempt to obtain control of furnace exit gas temperature, the coal nozzle tips were arranged for lateral adjustment; that is, the size of the firing circle could be varied. With large firing circles, the convection heat absorption by the furnace walls was increased, but a greater amount of ash

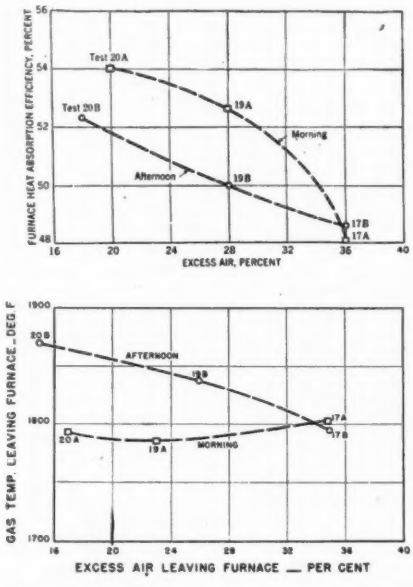


Fig. 3—Heat absorption vs. excess air

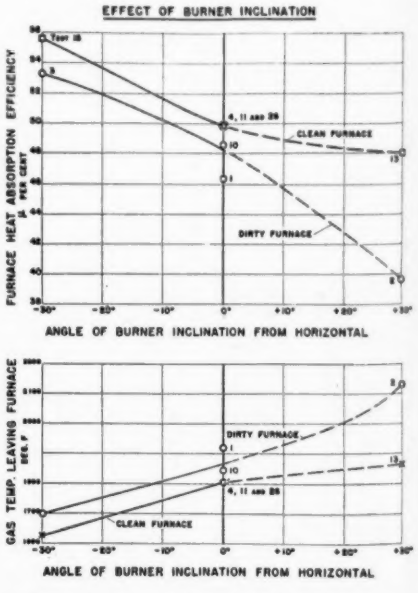


Fig. 4—Heat absorption vs. burner inclination

accumulated on the furnace walls and thus nullified the gain in absorption.

The next step was to design the tangential burner so that it could be moved vertically. The first experimental burner of this type was installed in one of the units at Buck Station of the Duke Power Company. Heat-absorbing test elements were located in the walls and tests were run to determine the variation of heat absorption in these elements for various angular positions of the burners. These results were encouraging, although the amount of angular tilt of the coal nozzle was limited by the furnace construction. In addition, we neglected to have the secondary air flow parallel the direction of the fuel. The first actual contract provided with the vertically-adjustable, tangential burner was four units at the Marysville Plant of the Detroit Edison Company. Here the air nozzles move with the coal nozzles. Since the floor screen in this case limited the downward tilt of the burner, all subsequent contracts were provided with water-cooled hopper construction, such as shown in Fig. 1, which represents a unit at the Tidd Station of the Ohio Power Company.

At Tidd Station, the Special Research Committee on Furnace Performance Factors, in cooperation with the Fuels, Power and Heat Transfer Divisions of the A.S.M.E. and the Bureau of Mines, ran a large number of tests to determine the variation in heat absorption in a pulverized coal-fired water-cooled steam boiler furnace. These data in very complete form are now available. Part I of four papers outlines the variations in heat absorption as shown by measurements of the furnace temperature of the exposed side of the furnace tubes. The ΔT or surface tube wall temperatures above saturation temperature have been plotted as isotherms to show the relative heat absorption pattern in the furnace. Fig. 2 selects three tests of near uniform loads to show the heat absorption pattern for three different burner positions. In the upper right corner are plotted the absorption rate curves for the three tests. In all the tests, rating and burner position were held constant and data were obtained on the effect of furnace heat absorption efficiency due to changing conditions of ash deposits, variation of excess air and variation of burner position.

Figs. 3 and 4 represent test data at Tidd plotted for furnace heat absorption efficiency against variation of excess air and for burner position, respectively. The lower groups of curves are these data converted to terms of furnace exit gas temperatures.

Until 1947, all the steam generating units then in operation and equipped with vertically-adjustable, tangential burners were so arranged that the burner movement was controlled manually. The gas bypass dampers on these units were arranged for automatic control. In early 1947, the first installation was equipped with automatic control of the burners. This was at the Glenwood Landing Station of the Long Island Lighting Co.

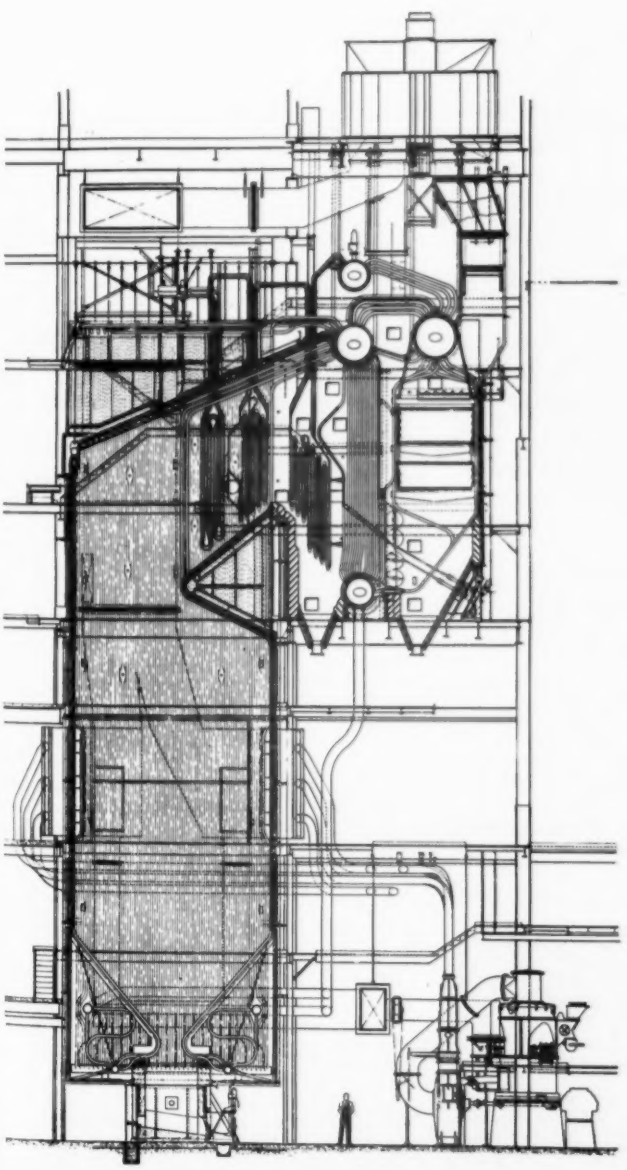


Fig. 5—Section through Cliffside unit

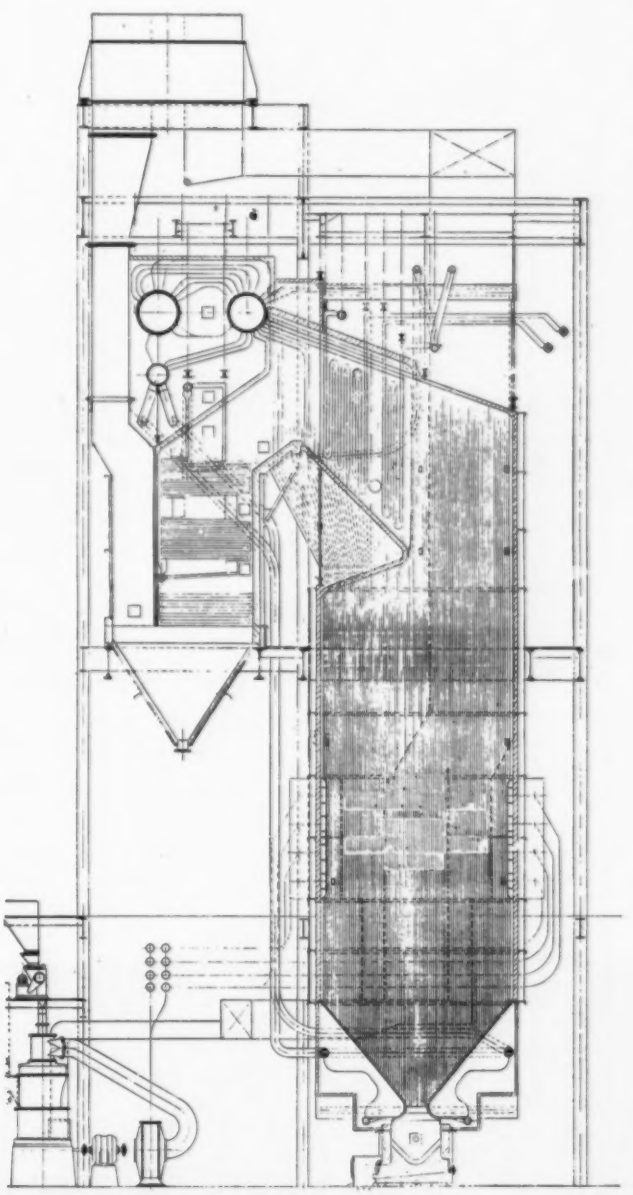
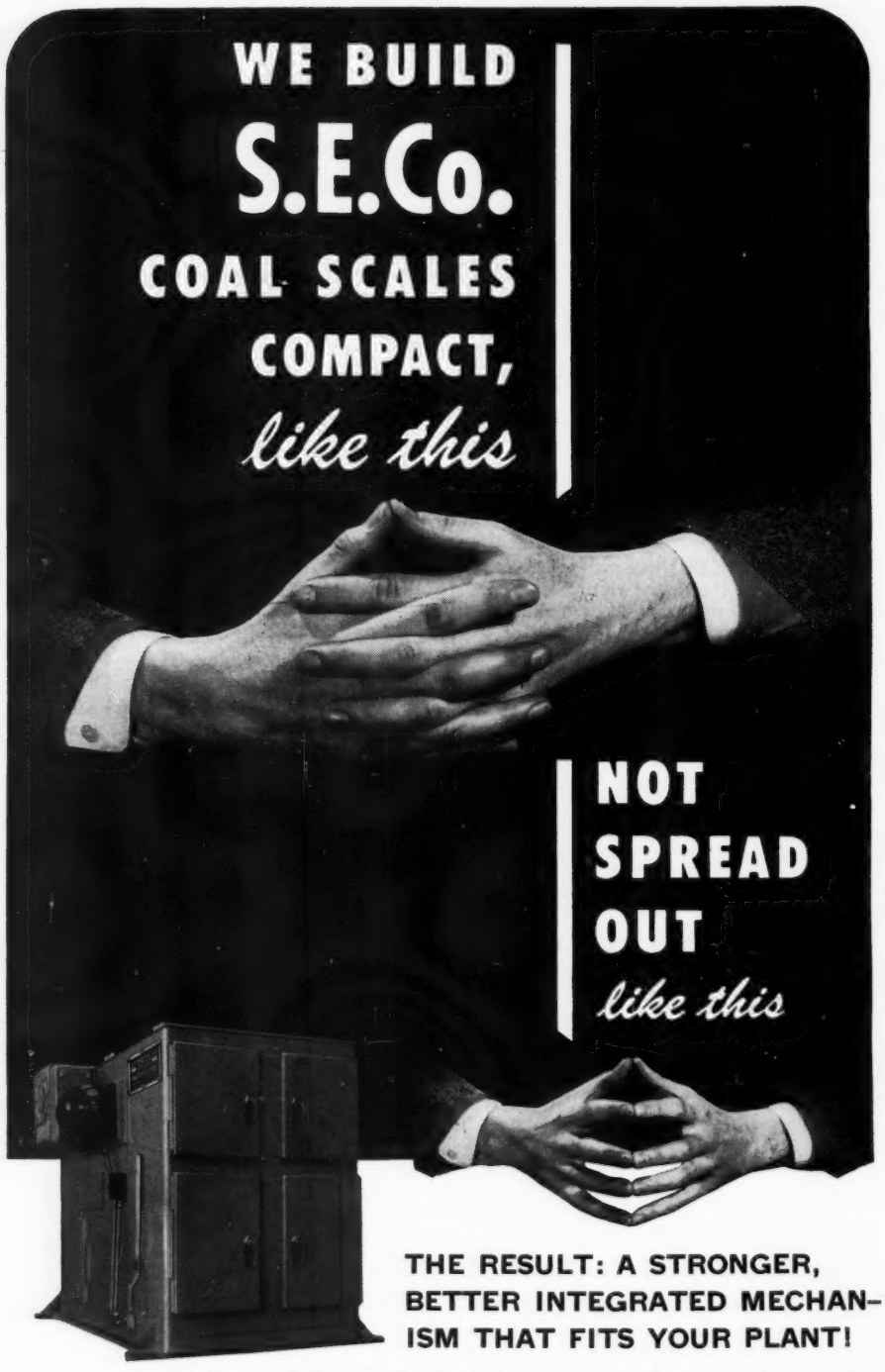


Fig. 6—Typical reheat unit of latest design



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At Havana Station of the Illinois Power Company, three units are now in operation with automatic control of the burners.

It was evident from the accumulated test data with the vertically-adjustable burner that the furnace heat absorption efficiency could be established for a given furnace; therefore, that furnace exit gas temperature could be held under control. Of all the factors entering into steam generator design, the control of furnace exit gas temperature is the most important. Knowing that gas temperatures entering the convection heat-absorbing surfaces can be maintained within narrow limits, it is relatively easy to design the heat-absorbing equipment beyond the furnace. It is essential, however, to arrange this surface to produce the required performance with low draft loss across the unit.

The earlier steam generator designs were severely baffled to obtain high gas velocities. This was done to provide high rates of heat transfer, thereby reducing the required heating surface and keeping the cost of the unit within economical limits. High gas velocities resulted in slagging of the first boiler bank and superheater and in erosion of the tubes of the boiler, superheater and economizer. The next step to increase availability was centered in the design shown in Fig. 5. This is the first of two units to be placed in operation at the Cliffside Station of the Duke Power Company. The burners are the vertically-adjustable, tangential design, but not as yet arranged for automatic regulation. The superheater, boiler and economizer surfaces provide for low gas velocities. The overall gas draft loss from the furnace to the air preheater outlet is less than 7 in. wg at the design load of 620,000-lb per hr evaporation. Many units of similar design are now under construction and all have bypass dampers for supplementary steam temperature control.

As test data continued to be accumulated, showing results in obtaining gas temperature control with the adjustable burner, it became possible further to simplify the design of the unit beyond the furnace. Two units of 800,000 lb of steam per hour capacity as shown in Fig. 7, are now under construction for the Richmond Station of the Philadelphia Electric Company. Another unit of similar design is under way to be installed in the Whitesburg Station of the Georgia Power Company. This design eliminates all boiler surface and consequently baffles. The drums and downtakes are out of the gas pass. There are four simple sets of steam generating surfaces and these are the four furnace walls. Spray-type desuperheaters are provided only as an emergency temperature-limiting device, such as for low feedwater temperature caused by feedwater heater outage.

Therefore, our present-day steam generator has a large furnace as measured in terms of Btu per cu ft or Btu per sq ft of radiant projected surface when compared to values in practice a few years back. The furnace walls comprise closely spaced tubes. There is no exposed refractory within the furnace. The type of burner used provides control of the furnace exit

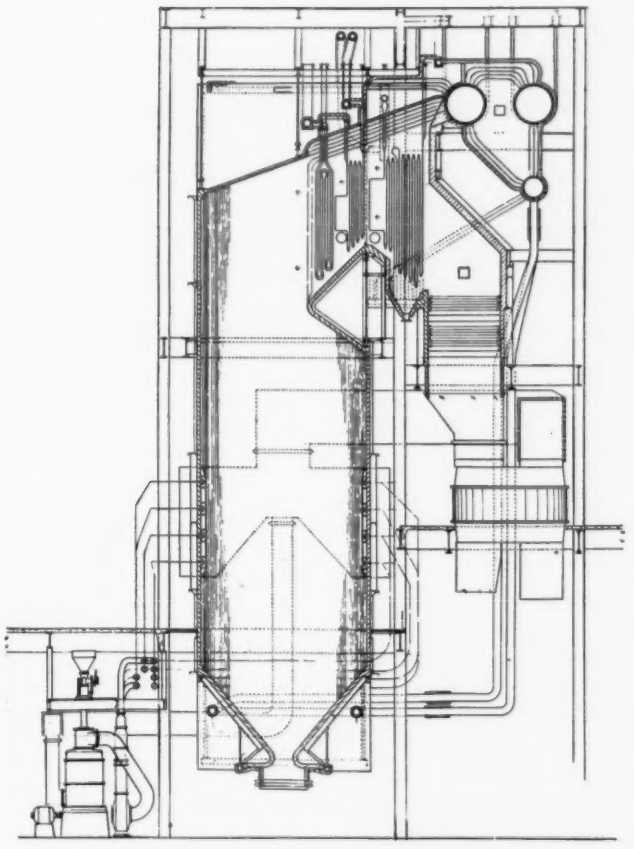

Fig. 7—Section through Richmond unit

gas temperature by using partial or all of the radiant heat-absorbing surface, as the nature of load or coal conditions dictate. The superheater and economizer are arranged for low gas velocities over their surfaces. Baffles have been eliminated and the draft loss is low.

The reliability of today's steam generator for continuity of service has encouraged the steam plant user to design his plant in units of one steam generator to one turbine. It is fortunate that this condition exists as the rising costs of fuel, material and labor have directed attention to the reheat cycle. The costs of piping, fittings, superheater and reheater materials entering into a reheat steam generator demand simplification of the steam plant arrangement. The single reheat steam generator and reheat turbine ably fulfill this requirement. Quite a number of reheat units have been ordered of which Fig. 6 is typical.

To conclude, it must not be assumed that steam generator design has gone as far as it can go. The manufacturer is constantly carrying out research and development work. The next ten-year period may bring forth design development far greater than has been experienced in the past ten years. The progress that has been made over the past years can be attributed to a large extent to the fortitude and patience of the steam plant user and his staff of engineers.

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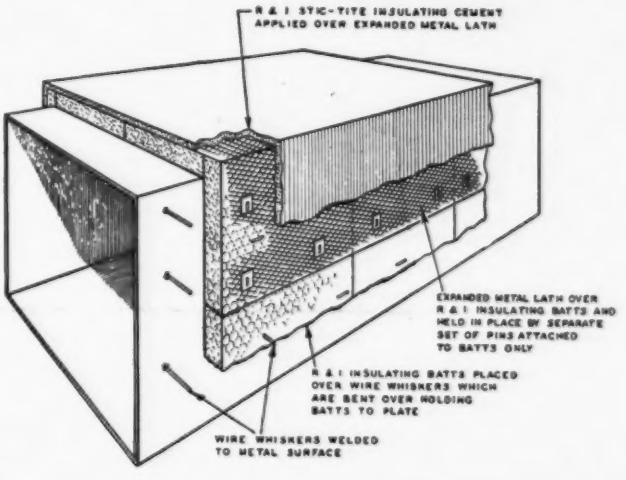
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Progress in the Coal-Burning Locomotive Project

REPORTING on the status of the coal-burning, gas-turbine locomotive project which has been carried on for the last four years by the Locomotive Development Committee of Bituminous Coal Research, **C. K. Steins,** mechanical engineer of the Pennsylvania Railroad, told the National Coal Association on October 5 that a satisfactory pulverizer and combustor, as well as a dependable method of cleaning the products of combustion, still presented a problem. In other words, as he expressed it, "Much hard work remains and the coal-burning, gas-turbine locomotive is not just around the corner."

It will be recalled that concurrent with the research, contracts were let some time ago for the building of a 4200-hp locomotive by the American Locomotive Company using an Allis-Chalmers gas turbine and a 3750-hp Baldwin locomotive using an Elliott gas turbine. The expected thermal efficiency of a coal-fired, gas-turbine locomotive with electric transmission is around 20 per cent, compared with 26 per cent for the diesel electric and $5^1/_2$ to 6 per cent for the modern conventional steam locomotive.

Some Problems Encountered

Commenting upon some of the key problems encountered, Mr. Steins gave a résumé of what had been accomplished to date. This was essentially as follows:

First, a coal bunker must be carried on the locomotive for run-of-mine coal with a crusher to break up the large lumps to minus 2 in. size. The hopper must be arranged with heating means to reduce the moisture content to not over 5 per cent, and from there the coal is to be carried by a stoker-type conveyor to a preliminary crusher which will bring the coal down to around minus 16 mesh (about the size of granulated sugar). It must next be pulverized so that not less than 90 per cent will pass through a 200 mesh and a large portion of this through a 325 mesh, corresponding to flour, in order that the particles may be burned in the combustion chamber in about two-tenths of a second. While it would be desirable to combine the preliminary crushing and final grinding in one step, indications are that the mill might to be too large to be accommodated on the locomotive and the power to drive it would be of the order of 200 hp, which seems excessive.

Efforts have been made to attain the final size by picking up the particles in a fast-moving stream of air and smashing them against a target of highly erosion-resistant material. For this purpose a rotating cylinder, or wheel, is employed with pockets in the periphery. These are filled by gravity as they pass under the hopper of a small bin filled with the granulated-size coal and as they reach the bottom position a stream of air at 160 psig removes the coal. The pocketed wheel is designed with 0.004 in. clearance to prevent the air from flowing back into the bin. After a number of failures in building these wheels, one was constructed which gave good performance after approximately fifty hours of testing.

The theory previously held that degradation resulted from filling the coal pores with high-pressure air and suddenly relieving the pressure by passing through an orifice and thus exploding the coal particles has been shown by subsequent research to have little substantiation, and that degradation really results from smashing the coal against the target. Some of the hardest known materials have failed to withstand the impact of the coal particles after only a few minutes of operation, but targets of cast tungsten carbide are now giving good results. However, it begins to appear that one target may not be enough as a few of the coarse particles bounce off. These will have to be removed from the stream by centrifugal action and smashed against a second target.

The combustion chamber still presents a major problem. Combustor development is being carried on at Battelle in Columbus, O., and at the Alco Products plant at Dunkirk, N. Y., as well as at the Kaiser steel plant, Fontana, Calif., which is the only place where a sufficient quantity of compressed air is available for full-scale experimentation.

One combustor will be sufficient for the Allis-Chalmers turbine, but two in parallel will be required for the Elliott turbine, because the latter is designed to operate at lower pressure and temperature. The combustor heat release figures out $1^1/_2$ million Btu per cu ft per hr.

"A great deal of valuable combustion information," said Mr. Steins, "has been developed at Battelle, as well as at Fontana and Dunkirk, but we have warping problems, localized burn-outs, localized incrustations, and difficulties in operating over the range from idling to full load, so it cannot be said now that we have all the answers and are ready to go ahead and build."

With reference to the problem of cleaning the products of combustion before entering the turbine, there is evidence that particles under 20 microns diameter will not harm the turbine blading, but the larger particles have to be removed from the gas stream with minimum pressure drop. After several months of work it was believed that a battery of small cyclone separators was the answer to this problem, but recent long-time tests at Dunkirk indicated that the burning which went on in these tubes was sufficient to ruin them. Hence two types of cleaners are now being designed which appear to have possibilities.

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Engineers Adopt Code of Ethics

Mindful of the large number of young men preparing for the engineering profession, the Engineers' Council for Professional Development has adopted a "Canons of Ethics for Engineers," especially to serve as a moral guide to young engineers as they progressively assume professional responsibility. The Canons supplement the engineering tradition of honest public service and the example of professional leaders.

Dishonesty and discourtesy are relatively unknown in the professional conduct of engineers. In fact, so effective has been the unwritten moral code of the profession that many engineers opposed at first the suggestion that a formal code was needed and cited the low incidence of unethical practice among engineers. Some felt the Golden Rule was all that was needed. Since its recent adoption by ECPD, however, more than 25 national and local engineering societies and councils have incorporated the Canons as part of their constitutions.

Increasing support has come from engineers concerned lest union appeals for the sympathy of the young graduate should lead them away from the established paths of professional development.

The Canons spell out the relationship of the engineer to his client, his employer and the public, the keystone of professional conduct being *integrity*.

The engineer must "interest himself in public welfare and be ready to apply his special knowledge to the benefit of mankind." In his relations with the public, he is directed to extend "public knowledge of engineering" and to discourage "the spreading of untrue, unfair and exaggerated statements regarding engineering.

"He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission or other tribunal."

In his relations with clients and employers, he will "act as a faithful agent and trustee. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

"He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client and employer."

The Canons direct that in his relations with his colleagues in the profession, "He will take care that credit for engineering work is given to those to whom credit is properly due. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ. He will not become associated in responsibility for work with engineers who do not conform to ethical practices."

The Canons have been attractively printed on a $9\frac{1}{2} \times 14$-in. card for framing and in the standard $8\frac{1}{2} \times 11$-in. size for general distribution to the engineering schools and professional societies. The large size is in two colors and sells for 50 cents per copy. The smaller size sells for ten cents per copy, or five cents when purchased in bulk. Copies may be ob-

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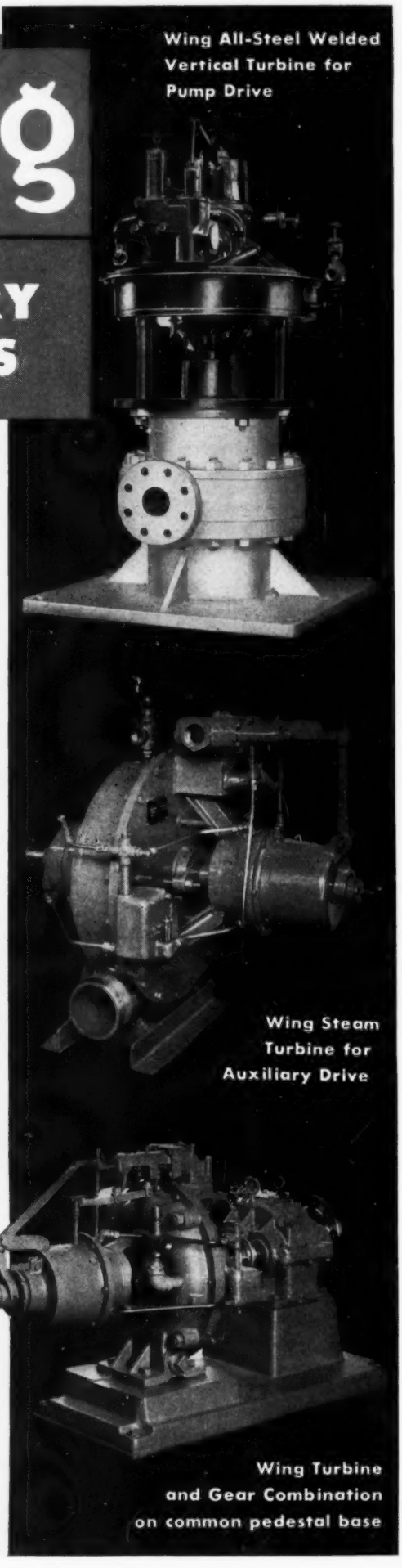

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The ECPD, it will be recalled, is a conference body organized by the engineering profession to enhance the professional status of the engineer through the cooperative effort of national engineering organizations concerned with professional, educational and legislative phases of engineers' lives. The following organizations compose its membership: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, The Engineering Institute of Canada, American Society for Engineering Education, American Institute of Chemical Engineers and the National Council of State Boards of Engineering Examiners. Its work is done through four major committees: student selection and guidance; engineering schools; professional training; and professional recognition. Perhaps its most significant work has been the accrediting of engineering schools.

Joint Fuels Conference Program

The Annual Joint A.S.M.E.-A.I.M.E. Fuels Conference is scheduled for November 3 and 4 at the Greenbrier Hotel, White Sulphur Springs, W. Va. Its tentative program is as follows:

Wednesday, 10 a.m.

"Work of the Geological Survey on Coal and Coal Reserves," by Paul Averitt, U. S. Geological Survey.

"Coal and Synthetic Liquid Fuels," by J. D. Doherty, U. S. Bureau of Mines.

Wednesday, 12:15 p.m.

Luncheon Meeting: "Mechanical Mining in Europe," by G. R. Spindler, Joy Mfg. Co., Brussels, Belgium.

Wednesday, 6:30 p.m.

Banquet and address by President E. G. Bailey on "Opportunities in the Field of Fuels"; also presentation of the Percy Nicholls Award for 1948 to Ralph Sherman of Battelle Memorial Institute.

Thursday, 9:30 a.m.

"Organizing and Financing Cooperative Research," by Elmer R. Kaiser, Bituminous Coal Research, Inc.

"An Evaluation of Residential Stoker Coals," by Harlan W. Nelson and James B. Purdy, Battelle Memorial Institute.

"Coal Dock Operations of the North-Western-Hanna Fuel Co. at the Head of the Lakes," by J. T. Crawford, North-Western-Hanna Fuel Co.

Thursday, 2:30 p.m.

"Correlation of the Performance Characteristics of Domestic Stoker Coals with their Chemical and Petrographic Composition," by R. J. Helfinstine and G. H. Cady, Illinois State Geological Survey.

"A Study of Coal Classification and Its Application to the Coking Properties of Coal," by Michael Perch and C. C. Russell, Koppers Co.

NEW EQUIPMENT

Refinery Capacity Reaches New High

Petroleum refineries of the United States had record-breaking rated operating capacities of 6,034,252 barrels of crude oil per day at the beginning of 1948, an increase of nearly a half-million barrels daily compared with a year previous, according to the latest annual survey of petroleum refineries and cracking plants by the Bureau of Mines.

Texas, with 80 refineries and one under construction, led other states in the number of installations and also was the leading state in the crude-oil throughput capacity with 1,722,200 barrels per day. California's 61 refineries had a rated capacity of 1,093,700 barrels per day; Pennsylvania's 18 refineries had a potential capacity of 446,150 barrels per day; and Louisiana's 18 refineries, 433,900 barrels daily.

"VDI Zeitschrift" Again Available

Word has been received from Germany that the Vereines deutscher Ingenieure, the Society of German engineers, has again resumed publication of its well-known engineering publication, *Zeitschrift des Vereines deutscher Ingenieure* which was suspended during the latter part of the war when Germany collapsed. Prior to United States participation in the war many American engineers, who could read German, either subscribed to this magazine or were accustomed to peruse it in libraries. They will welcome the announcement that it has again become available.

Power Conference Scheduled

A Fourth Plenary World Power Conference is scheduled to be held in London in July 1950. Headquarters will be the building of the Institution of Civil Engineers, and the theme of the conference will be "World Energy Resources and the Production of Power." Work has already begun on the tentative program.

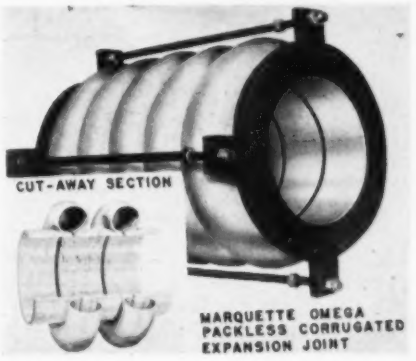
Hagan Changes

J. M. Hopwood, president of Hagan Corporation since 1918, has retired from this office and been elected chairman of the Board of Directors of the Hagan group, comprising Hagan Corporation, Calgon, Inc., Hall Laboratories and the Buromin Company. He is succeeded by **W. J. Erikson** who started his career with the Company as a draftsman over thirty years ago and subsequently advanced through various departments to the position of vice president in charge of sales in 1939.

Other changes in the organization include the election of **R. R. Donaldson** as vice president in charge of engineering; **M. J. Boho** as vice president in charge of Hagan sales; **E. W. Butzler** as business manager of Hall Laboratories, Inc.; and **Owen Rice,** former manager of the Calgon Threshold Department, as vice president in charge of commercial chemical sales of Calgon, Inc.

Expansion Joint

Pipe-line movement, axial, lateral, transverse or vibratory, is said to be taken up uniformly by self-equalizing corrugations of the new "Omega" expansion joint announced by Marquette Coppersmithing Co., Philadelphia, Pa. Stresses and fatigue rate are claimed to be negligible in comparison to conventional designs and much thinner metal can be used for a given pressure. By incorporating a circular cross-section the possibility of distortion is eliminated as pressure merely puts the metal under tension. Moreover, side walls of corrugations need not be depended upon to limit movement and equalizing rings are not necessary. As a result, these joints are relatively light and are made with an inside diameter from $^1/_2$ in. to 25 ft for any pressure or temperature within



ordinary practice. Ferrous and nonferrous metals can be used in their construction including stainless steel, monel, everdur, nickel and carbon steels.

Sleeves are seldom required to reduce friction as the inside surface is smooth and drains or blowoff connections may be readily attached for trapping condensate, flushing or ejecting sedimentation.

Recording Vibrometer

A new recording vibrometer which measures and records frequency, displacement and wave shape of mechanical vibration has been announced by General Electric Co., Schenectady, N. Y.

Built to operate either when mounted on a fixed base or held in the hands, the vibrometer weighs only 7 lb and is less than 8 in. in length. It was developed for application in testing all types of reciprocating and rotating machinery within a vibration frequency range of 10 to 120 cycles per second. It records both steady-stage and transient vibrations.

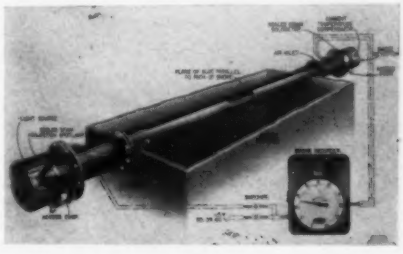
A prod extending from one side of the vibrometer is set in motion when held against a vibrating body. This motion is amplified by a cross-spring arrangement and transmitted to a stylus which inklessly records the vibration on wax paper, thus making available a permanent record for vibration analysis of equipment. Another stylus produces a timing mark near

the edge of the wax paper every one-third of a second. Both the chart speed and the interval between timing marks are governed by a synchronous motor operated from a 115-volt, 60-cycle power supply. Two push buttons are provided to give chart speeds of 1 in. per sec and 3 in. per sec. Motion of the stylus on the chart can be observed through a window in the top of the all-aluminum case.

Smoke Density Recorder

Bailey Meter Co., Cleveland, O., has developed a new electronically operated smoke density recorder. This consists of a standard Bailey electronic recorder, a bolometer-type smoke detector and a sealed-beam light source.

The bolometer smoke detector and the sealed-beam light source are used as the primary element and are installed on opposite sides of the smoke passage as shown in the illustration. Briefly, the bolometer principle as here used is similar to that employed by astronomers for measuring the radiation from stars. The amount of radiation reaching the filament is dependent upon the density of the smoke or dust, and the temperature of the filament depends upon the amount of radiation reach-



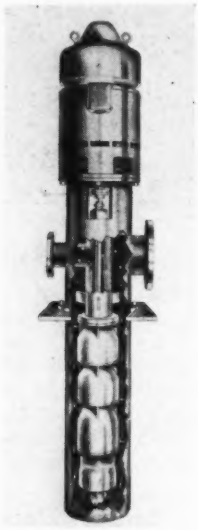
ing it. This filament temperature is measured by the electronic recorder in terms of smoke density.

Voltage drop across the bolometer filament is balanced against that across a motor-driven slide-wire unit in the recorder casing; and when temperature of the filament changes, the potentiometer becomes unbalanced and the slide-wire unit is automatically repositioned to re-

store the balance. The recording pen is directly connected with the slide-wire unit.

Pump for Limited Suction Head

The illustration shows a Byron Jackson Co. multi-stage vertical pumping unit designed for service where the net positive suction head is limited. The unit is mounted in a barrel from which it takes suction and the base of the pump is located at ground level. This does away with the



necessity of providing sufficient net positive suction head by either raising the vessel or excavating a pit to lower the pump.

These pumps are standardized in four sizes with 8-, 10-, 12- and 14-in. barrels which range in capacity up to 1000 gpm, although larger sizes can be furnished up to 5000 gpm.

Rust Inhibitor

An inexpensive, rust-prevention compound has been developed by the research department of the Sinclair Refining Co.

Known as RD-119, it is now being added to all Sinclair petroleum products as they flow through pipe lines to distribution points. Only a little more than $2^1/_2$ gallons are said to be required to give rust-preventing qualities to 42,000 gallons of petroleum products.

In the accompanying illustration the steel bar at the left shows a heavy deposit of rust after immersion in ordinary kerosene, whereas that at the right appears rust-free after immersion for the same length of time in kerosene containing 0.007 per cent by volume of RD-119.

Wide-Range Oil Burner

A new mechanical fuel oil atomizer having an extremely wide range and eliminating the necessity of changing sprayer plates is now in production by The Engineer Co., New York. This new Enco atomizer has a capacity range of 10 to 1 without returning or recirculating oil which is delivered to the atomizer at 300 psi (maximum viscosity 150 S.S.U.).

Variation of output is obtained within the atomizer by manual or automatic adjustment of a hand wheel. This eliminates cutting burners in and out of service to control load range.

Use of this constant oil pressure is said to produce uniform high quality atomization over the entire load range. Greater load ranges are possible with higher oil pressures.

Soot Remover

A new soot remover, designated as "Nalco SR-150," has been brought out by National Aluminate Corp., Chicago, Ill. Its action is explained by its ability to lower the ignition temperature of the soot to 775 F where normal furnace temperatures will burn it off. Untreated coal soot burns at about 1135 F. The material is in powdered form and vaporizes upon contact with the fire bed; these vapors then are said to penetrate the soot and bring about its ignition.

New Catalogs and Bulletins

Anti-Corrosion Materials

The International Nickel Co., New York, has issued a 24-page booklet dealing with the application of monel, nickel and inconel in the manufacture of some 200 standard industrial products in 47 classifications as a means of combating corrosion.

Control Valve

A new publication has been issued by Cochrane Corp., Philadelphia, describing its "Hydromatic Single Control Valve," now being made standard equipment on Cochrane Zeolite softeners and pressure filters. With this valve all the normal functions of a valve nest are integrated and controlled by one single valve and the power for operation is provided by the raw water itself.

Fans

Buffalo Forge Co., Buffalo, N. Y., has brought out a 68-page booklet replete with information on its "Limit-Load" conoidal fans. Following descriptive matter with illustrations are performance curves, installation diagrams and tables giving all essential dimensions and other data for various size fans.

Gas Analyzer

Bulletin No. 213 of the Burrell Technical Supply Co., Pittsburgh, Pa., contains descriptive matter and full directions for using its "Indusco Gas Analyzer," one model of which is an instrument for measuring carbon dioxide, oxygen and carbon monoxide and the other for measuring combustibles such as hydrogen and methane.

Ion Exchangers

A most interesting and readable 24-page brochure describing how the ion exchange process works has been issued by The Resinous Products & Chemical Co. of Philadelphia. It gives special attention to four new adsorbents, members of the Amberlite family of synthetic resins, which open up new concepts of ion-exchange performance. A comprehensive bibliography of articles, papers and reports of the subject is appended.

Motors

Two new catalogs have been issued by Electric Machinery Mfg. Co., Minneapolis, Minn.—one dealing with heavy-duty squirrel-cage induction motors and the other with heavy-duty synchronous motors, the latter ranging up to 5000 hp. In each case construction details are shown by cut-away wash drawings, and essential application data are included.

Smoke Recorder

Bulletin No. 20-A of Brooke Engineering Co., Philadelphia, describes its electric-eye smoke indicator now being adapted to the control of over-fire air to prevent smoke in coal-burning furnaces.

With the system described a light beam projected across the flue shines on a photoelectric tube which measures the smoke density. When the density increases beyond a predetermined value, a red warning signal light flashes and a timer relay circuit is closed. This starts the air jets which remain on during a period for which the relay is set and upon completion of the time cycle the jets are automatically turned off.